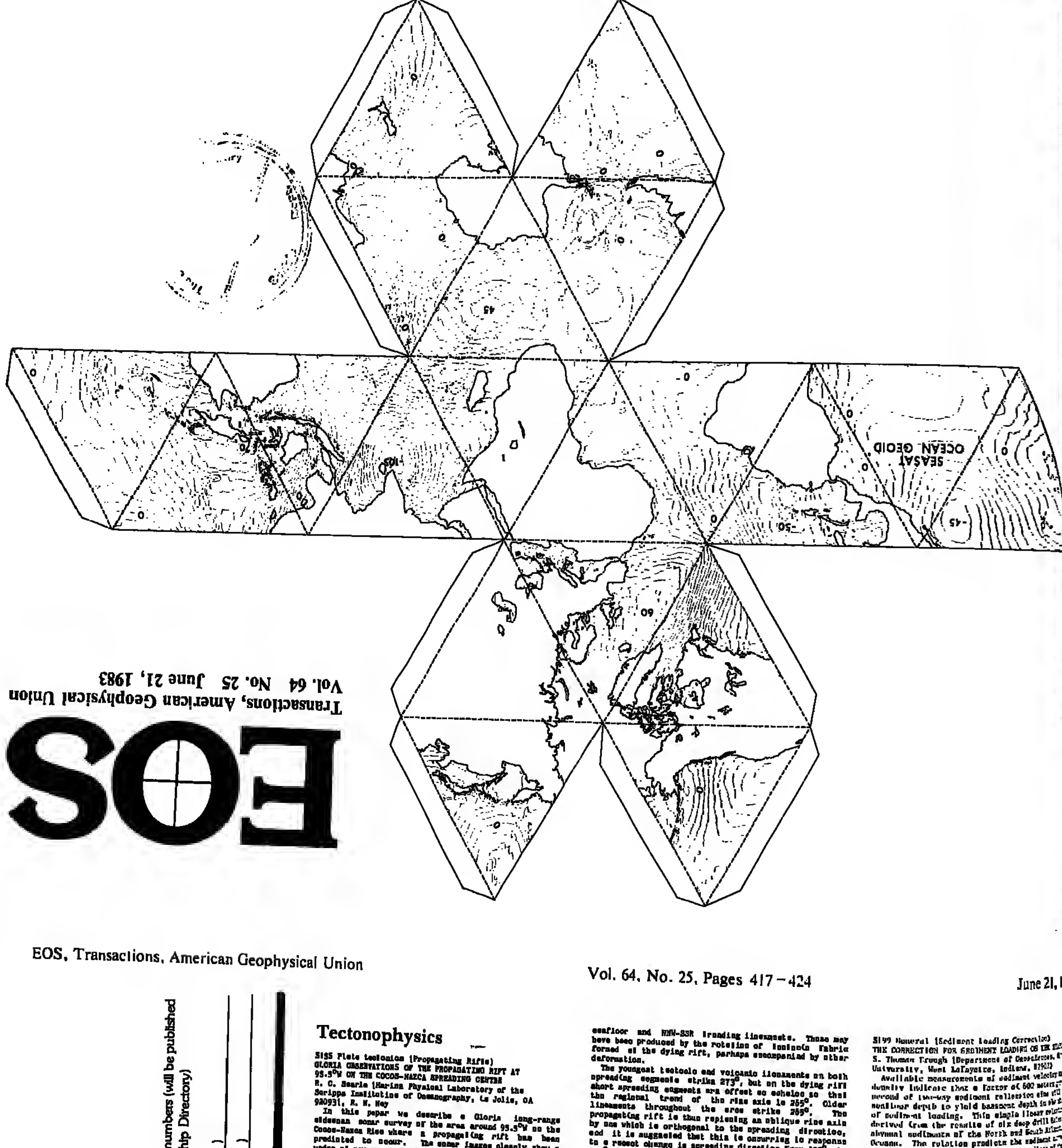

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Tectonophysics

GLORIA observations of the propagating rift at 95.5°W on the Cocos-Nazca spreading centre

Geophysical Research Letters

A Climate Hypothesis Describing the Solar-Terrestrial System as a Frequency Domain With Specific Response Characteristics

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The evidence for and against solar variability influencing weather and climate is beset by conflicting results (e.g., see Goldberg, 1982). This article will examine a new point of departure that is designed to complement simple cause-and-effect methodologies. The study is based upon an analogue to contemporary quantum physics.

Individual atoms are known to exhibit discrete absorption and emission responses to incoming radiation. John Jacob Balmer's 1885 description of the visible lines in the hydrogen spectrum was soon extended by Lyman and Humphreys to include both the ultraviolet and infrared components defining the simplest atomic element. In the late 1970's I decided to test a climate concept based upon the known variability of incoming UV radiation and outgoing infrared that also displays a similar discrete frequency response. This response is primarily controlled by the triatomic molecules of O_3, H_2O, and CO_2 that exist as diabatically important trace gases within earth's atmosphere.

The experiment produced its most notable success in predicting the 1981–1982 winter temperature departures evaluated by a power spectral technique [*Paine*, 1982]. These results were promptly followed by a spectacular failure this past winter when errors of up to 16°F between the observed and the expected departures were registered over the Midwest.

The elapsed time between these two results gave ample opportunity for speculating upon why the complexity of climate might be well suited to the worldview offered by quantum theory. Both the success and the failure focus on the postulated importance of significant changes of atmospheric stability by diabatic processes that is in keeping with the emphasis provided by Max Planck in 1900. Specifically, Planck had the insight to avoid a detailed description of the diverse phenomena associated with electromagnetic physics. He strove instead for a single mathematical statement that would describe how a simple harmonic oscillator was excited or damped by changes in the stability of its surrounding environment. In doing so, he accomplished a unifying radiation law that was able to accommodate not only long (e.g., infrared) and short wavelengths (cosmic through X rays), but ultraviolet frequencies that appear to trigger important changes in both the biological and the climate domains.

Tropospheric-Stratospheric Stability

Our discussion begins with the documentation of stability changes linked to the onset of a major drought. I have always been curious about a discrepancy that first came to my attention in the mid-1960's: namely, preparation of temperature-height profiles for the 'U.S. Extension to the ICAO Standard Atmosphere' (Figure 1) revealed some significant differences between data gathered in 1054 versus that compiled in 1962. The 1954 sounding profile came during a sunspot minimum, and it depicted an isothermal lapse rate above the tropopause boundary to near 25 km; the 1962 profile showed a more confined isothermal lapse rate (10–20 km), while a modest thermal inversion was found in the 20- to 30-km layer. Rocketsondes confirmed that a strong inversion from 10 mbar (30 km) to 1 mbar (48 km) reflected maximal diabatic heating owing to oxygen photodisassociation that increased toward the stratopause boundary.

Such a discrepancy might have easily passed unnoticed, except that much of the Northeast experienced its worst drought of record from 1960–1966. *Namias* [1966] had shown that the driest period, as depicted in Figure 2a, was paralleled by abnormally cold continental shelfwater from 1963–1966. He used this anomaly to argue effectively that the chilling of the lower tropospheric column could be expected to enhance the static stability and thus decrease the vigor of precipitation events over the northeastern United States.

The 1962 temperature-height diagnosis of detectably greater stratospheric stability, commencing near 20 km, suggested that a kind of resonance in enhanced stability in both the lower troposphere and the stratospheric regimes may have contributed to the drought situation. Was it, therefore, only coincidental that the more stable profile in 1962 came only 4 years after the strongest sunspot maximum of record (200 sunspots), as monitored during the International Geophysical Year (1958)?

Likewise, the recent 1980–1982 composite of accumulated precipitation departures shown in Figure 2b, with its notable deficits to the lee of the Appalachian Mountains, follows closely after the second strongest (yearly) sunspot maximum of record. The excessive incoming ultraviolet, peaking near December 1979 as shown in Figure 3, would be expected to enhance the diabatic release of heat (142 J mol^{-1} $°K^{-1}$) associated with ozone production in the middle to upper stratosphere. The consequent downward diffusion of this heat could have conceivably strengthened the positive lower stratospheric lapse rate until 1987. (The forward phase shift in the 'solar-induced' stable mode shown in Figure 3 represents an idealized schematic. It is meant to account for the elapsed time of 2 or 3 years that would be required before the diffusion process significantly reduces the depth of the isothermal lapse rate.)

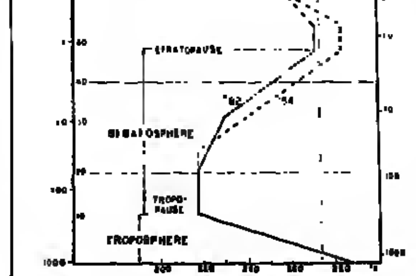

Fig. 1. Temperature height profiles to 60 km for the U.S. Standard Atmosphere, depicting the 1954 versus 1962 observed differences in stratospheric lapse rates above 20 km.

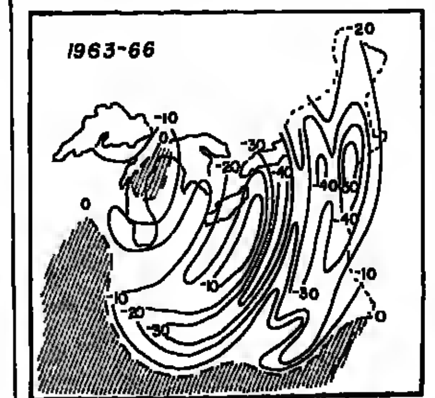

Fig. 2a. Observed 1963–1966 cumulative precipitation deficits. Isopleth interval equals 10 inches (254 mm). Maximum 1960–1962 cumulative deficits of 20 inches were confined to a narrow corridor extending from Concord, N.H., to Bridgeport, Conn.

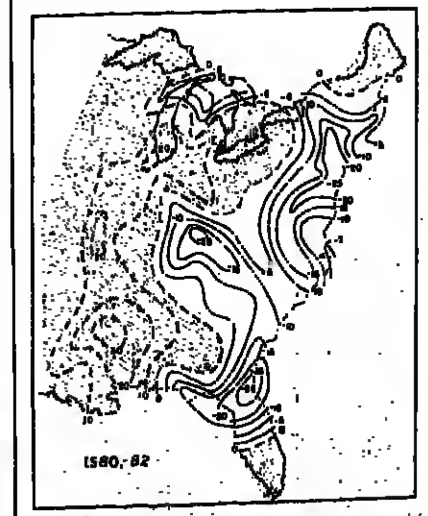

Fig. 2b. Observed 1980–1982 cumulative precipitation departures relative to 30-year mean. Isopleths labeled in inches; dashed lines and shading represent excesses, solid lines designate deficits. Sources include 1980–1981 Local Climatological Data (National Climate Center) and 1982 (preliminary data) published in the Weekly Weather and Crop Bulletin (NOAA/USDA Joint Agricultural Weather Facility).

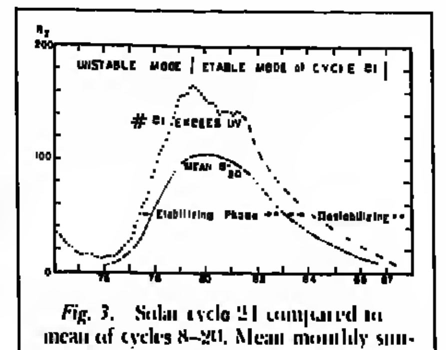

Fig. 3. Solar cycle 21 compared to mean of cycles 8–20. Mean monthly sunspot values (R_z) from Solar-Geophysical Data, U.S. Department of Commerce, Boulder, Colo. Date marks indicate June of each year; cycle 21 began June 1976 and is projected to end June 1987.

However, the April 1982 eruption of El Chichón added additional complexity to the situation. The volcanic debris observed reinforcement of lower stratospheric warming coming in phase with the quasi-biennial oscillation (QBO) may have been strong enough to override the expected trend in the East toward enhanced stability well above the tropopause. *Parker and Brownscombe* [1983] reported a +8°K (+3σ) warming at 30 mbar over equatorial latitudes, a situation that normally may have reversed the expected positive temperature gradient above 24 km. Either way, the phasing of the positive temperature trend induced by QBO-El Chichón working in consort to alter the lower stratospheric stability, or the coupled role of enhanced stability inferred from 1960 to 1966, directs our attention to the manner in which diverse energy sources are able to reinforce or to cancel one another.

On the Importance of Resonance

At the end of the severely cold 1976–1978 winters, my interest in the physics of climate grew when a Cornell colleague showed me a series of curves like that depicted in Figure 4. As New York's climatologist, Boyd Pack had been plotting the 20-year running averages of winter seasonal temperatures, utilizing data extending back to 1802. These curves indicated that the recent period over the interior Northeast has been cooler than any previous decade in the 20th century.

A careful inspection of the December–February running averages revealed a notable acceleration of longterm warming (1923, 1933) and delay in time-averaged cooling (1954, 1965, 1976) near the onset of five out of seven sunspot minima (↓). Two questions came to mind as I studied these curves: (1) What could give the temperature graph the appearance of the output generated by a thermal capacitor that slowly 'discharges' to reflect diminished heat input during one phase (maximum to minimum) of the solar cycle? (2) What would then cause this same thermal capacitor to 're-charge' vigorously (or entrain heat) beginning around sunspot minima? The answers might involve the tendency for cold air masses spilling southeastward from Canada to extract considerable latent and sensible heat from the Great Lakes or the nearby warm waters of the Gulf Stream. If so, then the geographical dimensions of these heat storage areas would present the potential for resonant interactivity between solar, atmospheric, and even hydrospheric energy sources.

From the quantum viewpoint, we can entertain the abstract notion that the Great Lakes exhibit natural harmonics in relationship to the 11.2-year periodicity of the sunspot cycle, just as this cycle is itself a harmonic of the 90-year Gleissberg cycle [*Agee*, 1980]. The large-amplitude patterning of the precipitation deficits shown in Figure 2a—looking very much like a 'standing-wave' configuration excited over and amplifying to the lee of the Great Lakes—suggests this simplifying concept is applicable to the physics of climate.

Nested primitive equation modeling of classic lake-effect snowstorms by using moist diabatic physics [*Kaplan and Paine*, 1973] had earlier revealed an overlooked subtlety in the dynamics of vigorous air-sea exchange: that is, not only does it require relatively cold flow down the length of the longest lake fetch, but the triggering atmospheric wave generates the largest response when the dimensions of the energy source or heat reservoir represent some harmonic of this wavelength.

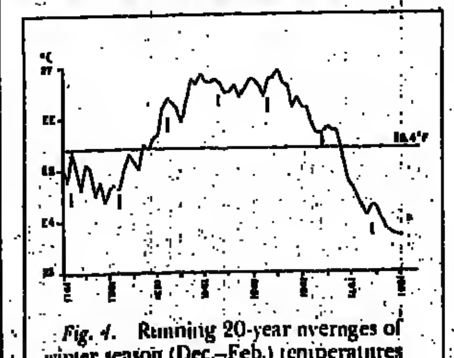

Fig. 4. Running 20-year averages of winter season (Dec.–Feb.) temperatures (°F) in the Finger Lakes region of central New York. Length of data record: 1802–1983. Arrows indicate timing of observed sunspot minima.

Climate Complexity and the Laplace Transform

Just prior to the unprecedented 1978–1979 winter with its severely cold departures across the entire contiguous United States [*Diaz*, 1980], Figure 5 was constructed from the observed cooling pattern exhibited since 1950 and was recently updated and extended to the expected timing of the next sunspot minimum in 1987. The mathematical formalism used to generate and interpret this curve is based upon a systematic and elegant procedure widely used in the study of feedback and control. The complexity of climate built upon forcing functions ranging over a vast variety of time scales seems particularly suited to this form of analysis because it requires knowing only the governing periodicities and response amplitudes characteristic of the dynamical system. (The 11.2- and 90-year sunspot cycles, plus the commonly observed range of winter averages in the Northeast spanning ±7°F (7°C)—or 0.7°F on the 20-year running average scale—set the necessary parameters in Figure 5.) In this treatment, one is asked to imagine a solar-terrestrial 'circuit' composed of diabatic energy capacitors, inductors, and resistors that are combined until one reaches a desired outcome replicating the behavior of the physical system at hand. The reader is referred to the appendix of *Sokolnikoff and Redheffer* [1966] for a more detailed elaboration.

The top right-hand corner of Figure 5 depicts the resultant Laplace transform of an 11.2-year periodicity drawn over three solar cycles, after first neglecting the superposed longterm periodicity from 1954–1987. The curve at the bottom of Figure 5 shows how the minima of observed Zurich sunspot numbers for cycles 18–21 captures the ensemble effect of enhanced heat entrainment commencing with 1954, 1965, 1976, and 1987. The latter year is the projected timing of the next sunspot minimum as documented in Figure 3 and *Lincoln* [1979].

The value in formulating this background trace is that it provides a quantitative point of reference for 'reading' either gradual departures from the idealized trace—like the recent flattening of the projected cooling trend in the 1980's—or the sharp departure associated with the 1982–1983 winter. In the former case, the particularly unsteady profile prior to 1920, and the flattened peak associated with the relatively warm winters in the 1940's, indicates that greater heat exchange fluctuations may prevail near the long-term winter temperature extrema. The recent 1982–1983 winter anomaly may therefore represent a return to a similar period of greater year-to-year uncertainty about seasonal departures. It is also interesting to speculate whether the 1983–1984 value for the 20-year running av-

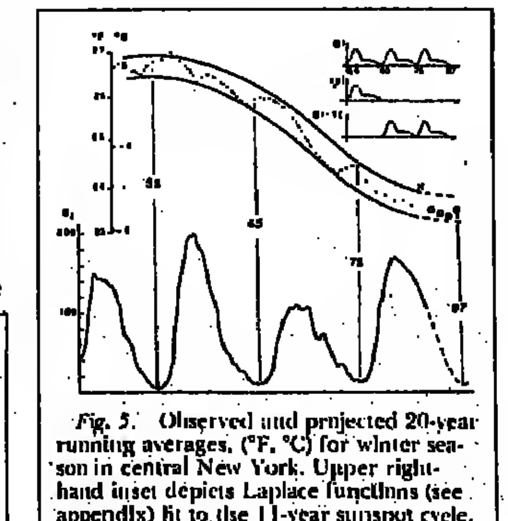

Fig. 5. Observed and projected 20-year running averages (°F, °C) for winter season in central New York. Upper right-hand inset depicts Laplace functions (see appendix) fit to the 11-year sunspot cycles years of minima as indicated. Zurich sunspot numbers (R_z) plotted at lower portion of diagram illustrate the observed (and 1987 projected) reversal in the long-term cooling trend at sunspot minima. Warm anomaly (cross) registered in 1982–1983 winter yielded a +10°F error in expected seasonal average based upon solar UV modulation (i.e., 29.4°F observed versus 19°F projected).

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erage will return toward the previous extrapolated value or remain near the new plateau established by last winter's anomaly.

A 'climate circuit' designed around the Laplace technique can easily include either a periodic QBO effect or a single-incident component like that of a strong volcanic event. Furthermore, the inferred alteration of stratospheric stability by El Chichón's sulfuric acid haze layer emphasizes the important role of anomalous albedo duration at any atmospheric level. For instance, the record length of snowcover throughout the Northeast in the 1977–1978 winters [see *Dewey and Heim*, Jr., 1982] had earlier suggested the need for adding an 'enhanced albedo' component to the mathematical circuit to account for lower tropospheric chilling. This cooling dropped the observed winter averages 2°F below the expected solar-induced departure, while the absence of an effective snowcover albedo this past winter may have contributed up to one-third of the +6°F departure (relative to the 30-yr mean) observed over western New York.

Direct Versus Indirect Solar Signals

Currie [1979] published evidence of a solar signal in surface air temperature over North America utilizing the maximum entropy method (MEM) of spectral analysis. The largest amplitude of the observed 10.7-year signal (0.3°C) was found over the Northeast. The depressed thermal peaks near the time of sunspot maxima led many investigators to postulate a direct sunspot-climate link; that is, the dark umbra/penumbra distinguishing sunspots have long been thought to reduce the net solar output by a few tenths of 1% [see *Hoyt*, 1979].

The indirect mechanism of ultraviolet control over diabatic heating of the troposphere by modulation of major storminess—enhanced from sunspot minimum-to-maximum—which is postulated here does share one thing in common with Currie's result. The inferred sunspot signals in both studies weakened toward the far South and were effectively absent to the west of the Continental Divide. In fact, this investigator found substantial differences in the 20-year running average curves across the 600-km length of New York state, seemingly dependent upon the proximity of the five regional profiles (averaging 12 stations per sector) to lakes Erie and Ontario. These differences appear to argue in favor of the importance of in situ diabatic heat sources in generating the idealized (indirect) 11-year signal, while latitudinal or continental dependency (direct solar heating and bulk heat transport) would help to shape such long-term references as the 90-year winter means of 25.4°F versus 18.7°F in central New York and the St. Lawrence Valley Region, respectively.

More recently, an 11-year thermal signal has been confirmed over northern Europe yet is notably absent over central Asia [see *Kerr*, 1982]. These equally meaningful null results obtained over certain portions of the globe, and not others, may be tied together by a common dynamical thread. For instance, the lack of a detectable 11-year signal on this continent occurs next to the cold upwelling of Pacific water along the West Coast. In central Asia, or Canada's Hudson Bay region, warm surface waters are essentially unavailable for heat transfer in winter because of their outright geographical absence or substantial snow and ice cover. I refer to such regions as 'diabatically dormant' portions of the globe, just as other areas and atmospheric levels are qualified as 'active.'

In the case of the far South (below 35°N), the cold air intrusions over the warm Gulf of Mexico are more sporadic from winter-to-winter than at the latitude of the Great Lakes (40°–45°N). The southern intrusions often produce the most effective atmospheric heat realization when latent heating is maximized farther north over the eastern United States, a process that requires major macrocyclogenesis and its embedded vigorous convection to reach peak efficiency.

Role of Intense Convection in Coupled Dynamical Studies

Before attempting to relate how UV modulation of stratospheric stability might help to account for a solar-induced thermal signal, I feel it is important to explore the possibility that the hydrological cycle and the observed discharge of a major northeastern river may be linked to the 11-year cycle. This will lend added credibility to the postulated importance of latent heat release, since only convective storms can approach the 100% efficient conversion of water vapor into condensate. In contrast, macroscale uplift in winter cyclones absent convection is only about one tenth as efficient in precipitation production. We will also want to document that triggered convective activity in both the atmospheric and the continental shelfwater regimes has a crucial self-regulating role to play in maintaining the vigor of biospheric activity.

Figure 6a depicts the result of applying MEM to the 1900–1970 time series of the river discharge observed at Harrisburg, Pennsylvania, centered within the Susquehanna watershed. This 27,500 mi² drainage basin has only limited man-made modification above Harrisburg, and ranks as the largest such basin in the Eastern United States. The Susquehanna River is situated midway between the central Great Lakes and the mean location of the Gulf of Mexico stormtrack that runs between the Gulf Stream and the Appalachians. *May* [1981] found a 10.917-year periodicity and its first harmonic, as well as a possible reflection of the QBO. The same technique applied to the mean yearly sunspot number (1900–1970) revealed a 10.549-year power spectral peak, including its two harmonics at 5.280 and 3.429 years.

A prediction model described in May's M.S. thesis is an autoregressive or feedback system where 300 coefficient involve one-half the data length. The 1950–1970 test prediction from the 1900–1950 time series showed that individual 'flood' or 'drought' years were not necessarily captured by MEM; however, the 5-year composite of the integrated discharge was more skillfully represented. As a recent example, the 1971–1991 prediction shown in Figure 6b missed the excessive precipitation year of 1972 which included Hurricane Agnes and runoff from heavy winter snows generated by a major Nor'easter, but the outlook captured some of the record wetness in the late 1970's followed by the very dry beginning to the 1980's.

Embedded in this predicted period is the so-called New Jersey anoxia (oxygen-depletion) incident involving large kills of shellfish in the New York Bight region during the summer of 1976. This is the same year a similar anoxic condition of El Niño last occurred off Peru, prior to its 1982–1983 return that covered a record eight million square miles of the equatorial Pacific. (Although the 1975–1976 winter was also labeled of 'anomalous' character over North America, the first 2 months of that winter were distinguished by sharp cold over the East, as opposed to the record warmth that began the 1982–1983 winter. The detailed comparison between these two winters suggests care must always be exercised when assessing the relationship between +10°F departures over the northcentral United States and unusually warm Pacific water in the tropics. For instance, repeated cold outflows from Siberia maintained an unusually large and intense Aleutian low over the Gulf of Alaska, representing a very efficient sensible and latent heat pump near 60°N latitude [see *Wiin-Nielsen*, 1982]. However, it is true that the more modest 1975–1976 El Niño was marked by +4° to +6°F departures over the Northern Plains.)

In assessing possible anthropogenic (toxic waste dumping) versus environmental factors that may have contributed to the 1976 oxygen-depletion incident, I will quote from a summary by *Mooers* [1978]. It began by relating shellwater biological activity to horizontal kinetic energy profiles examined along the eastern seaboard. Both zooplankton and phytoplankton, plus fish, are associated with spectral density peaks in the frequency distribution that describes barotropic and baroclinic ('storm') disturbances in this domain, as well as annual, diurnal, and intertidal cycles. Mooers continues:

'After a severe cold December and January, there was an early spring: Atmospheric warming produced thermal stratification plus snowmelt and river runoff and thus increased density

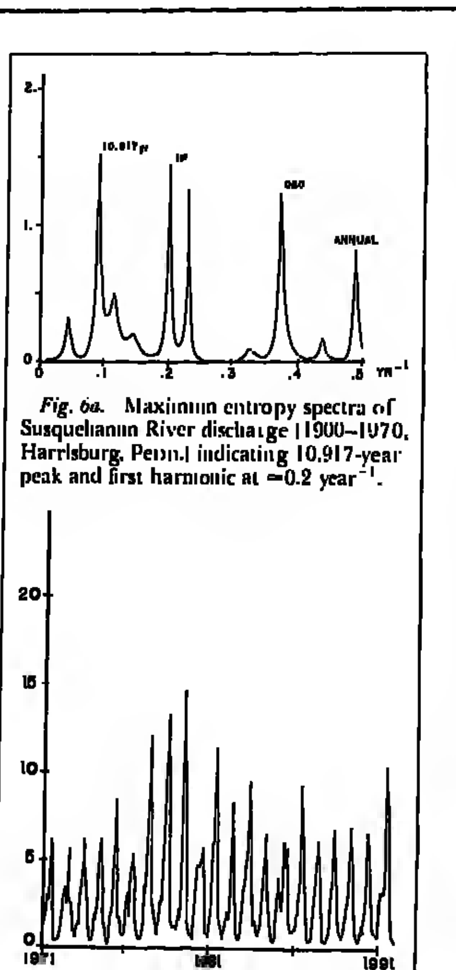

Fig. 6a. Maximum entropy spectra of Susquehanna River discharge (1900–1970, Harrisburg, Penn.) indicating 10.917-year peak and first harmonic at ≈0.2 year⁻¹.

Fig. 6b. Predicted mean monthly discharge (1971–1991) in ft³ s⁻¹. Both figures adapted with permission from *May* [1981].

stratification about a month earlier than normal. An intense and persistent bloom of *Ceratium tripos* in the region may have been 'supported' by this intense density stratification; its eventual decomposition could be expected to contribute to [a] reduction of the dissolved oxygen concentration in the lower layer. [Upper and lower layers are with respect to the thermocline, while 'supported' is a *double entendre:* (1) The strong density stratification physically supported the *Ceratium;* (2) it provided a physical niche they could exploit and monopolize to outcompete other phytoplankton for light and nutrients.] The anomalously early stratification obviously eliminated ventilation of the lower layer by free convection. Associated with the early atmospheric warming was an early cessation of the wintertime weather cycle of vigorous cold fronts and cyclones. This could be expected to reduce the amount of forced convection produced by wind stirring of the upper layer. Other factors came into play with a shift of the weather cycle. In early summer, a several-week period of weak but persistent winds with a poleward component occurred off New Jersey, driving coastal upwelling. Associated with the upwelling was an inwelling (onshore flow of lower layer water) of nutrient-rich and oxygenated water from the outer to the inner shelf. During this period, the dissolved oxygen concentration in the lower layer decreased at an anomalous high rate and reached a level much lower than the usual late-summer minimum.

Of special interest are the inferred roles of 'free' versus 'forced' convection in this incident. In the ocean, free convection is overturning due to negative buoyancy induced by cooling or evaporation at the sea surface. Forced convection refers to mechanical stirring due to wind-generated waves and turbulence in the upper layer, or tidal motion stirring the bottom layer. Helping to resolve the anoxia condition in late summer was Hurricane Belle which passed over the region as a small, swiftly moving, spiral-banded convective system with 93 mph squalls. Again, quoting from Mooers: 'This hurricane generated vigorous inertial oscillations and some wind stirring, but it did not overturn the water column . . . the stratification quickly "healed," leaving the ventilation of the lower layer to the normal autumnal cooling.'

Students of meteorology sometimes create an effective analogue to atmospheric convection in fluid tanks by injecting a 'milky' saline solution from a syringe into clear water, then videotaping the event with a camera mounted upsidedown. By scale similitude of the Froude number—or the ratio of the kinetic to potential energy characterizing a turbulent event—the final inverted image of the saline plume looks a great deal like the mixing of cloudy and clear air surrounding positive buoyancy accompanying a cumulonimbus. (A 1°C temperature excess in the cloud yields a buoyancy factor of 5×10^{-3} which can be easily matched by the saline mixture to give identical Froude numbers of 2×10^{-2}.) If the vertical mixing of life-supporting nutrients and oxygen is aided by storm-generated convection, is there a similar mechanism that might explain how macroscale cyclogenesis with its vigorous embedded convection is aided and abetted by solar modulation of incoming ultraviolet radiation?

Solar-Terrestrial Connection

Major storms with central pressures of less than 1000 mbar (100 kPa) are invariably accompanied by a break in the tropopause boundary which serves to separate the stratospheric and tropospheric regimes. (The height of the troposphere, globally averaging between 10 and 16 km, has been observed to oscillate by 0.5 km with an 11-year periodicity over the equatorial Pacific, peaking near sunspot maxima. This study by *Gage and Reid* [1981] was limited to data obtained from two radiosonde stations, the time series itself being restricted to two solar cycles. It would be interesting to perform a spectral analysis of the varying thermocline depth—the ocean's analogue to the tropopause—provided a more suitable time series was available.)

A tropopause break and its attendant frontal discontinuity (thermal inversion) enrich the troposphere with storm-producing cyclonic spin by creating the downward transport of stratospheric air. Such air is characterized by large magnitudes of positive potential vorticity or potential cyclonic spin once the atmospheric column in question is destabilized by diabatic heating at its base. Storms of this intensity are also found to enhance the planetary boundary layer's upward flux of sensible and latent heat by 1–2 orders of magnitude. The sunspot component of the quantum climate hypothesis effectively asks whether or not such incidents of tropopause folding and breaking are somehow augmented when a lessening of the incoming UV radiation results in significant episodes of lower stratospheric destabilization.

Unlike the positive buoyancy excited by the input of diabatic heat at the base of a tropospheric column, these occasions of stratospheric instability would most likely be attached to incidents of negative buoyancy or air that descends because it is colder than the surrounding environment. The farthest descent of negatively buoyant air would occur when the O_3-diabatic heat source and subsequent downward diffusion of heat had diminished, effectively replacing the modest inversion from 20 to 30 km shown in Figure 1 with an isothermal lapse rate below 27 km.

Such episodes of intense subsidence, distinguished by their descent of large positive values of potential vorticity, are most likely to be triggered by the momentum deposition arising from vertically propagating, internal gravity waves. These acoustically modified waves often originate in the troposphere wherever strongly sheared flow is found crossing undulating terrain [*Jones and Houghton*, 1971], as well as arising near the jet stream core within so-called "jet streaks" producing wave-induced (Kelvin-Helmholtz) turbulence.

The capability of vertically propagating waves to produce narrow zones of momentum deposition wherever the wave trace velocity encounters a background flow of equal magnitude is usually met at the level of the sharp transition in the lower stratospheric lapse rates. The momentum surges created at this level of deposition are capable of displacing relatively cold layers which then override warmer air, commencing the descent of the denser volume with its large potential vorticity toward the tropopause. This investigator has found that the above sequence of events typically precedes tropopause rupture by 6–12 hours [*Paine and Kaplan*, 1974].

The critical climate control of more frequent cyclogenesis in the troposphere could therefore be exerted by simply providing through UV modulation a deeper isothermal lapse rate in the lower stratosphere. (The El Chichón-QBO destabilization of this same zone is likewise postulated to have overwhelmed the current solar-induced tendency toward stabilization, perhaps even creating volumes with an uncharacteristic temperature decrease with height near 25 km to promote even more frequent macrocyclogenesis.) Equally vigorous packets of upward-propagating, internal gravity waves could only produce negatively buoyant plumes capable of reaching the tropopause boundary in the case of an isothermal (or even less stable) environment prevailing from 20 to 27 km. A modest inversion dominating at these levels would mitigate against high potential vorticity pools from ever reaching the troposphere. In this regard, it would be interesting to compare the mean stratospheric lapse rates prevailing during the very dry 1980–1981 episode that affected much of the contiguous United States, versus the more recent excessively wet period (1982–1983).

Normally, additional UV radiation accompanying strong sunspot maxima would be expected to maintain a modest inversion from 20 to 30 km, as in 1962. This stable mode is hypothesized to lead to a decrease in the number of exchanges across the tropopause boundary of downward flowing high potential vorticity pools, with a consequent decrease of air-sea interactivity tied to less frequent and intense major storm development over warm water source regions. Seen in this way, the sudden reversal in the cooling trend frequenting sunspot minima, as shown in Figures 4 and 5, represents a type of dynamical discharge that begins to release an increasing number of potential cyclonic spin "packets" (negatively buoyant plumes) built up during the stabilizing phase of the 11-year solar cycle.

Analogue to Planck's Law

The extreme sensitivity of tropospheric cyclogenesis to the depth of the stratospheric isothermal layer becomes more understandable when we consider that potential vorticity typically increases from 200 to 20,000 units (1×10^{-10} cm s °K⁻¹) between the height of the tropopause boundary to 30 km. Thus, the difference of only a few kilometers in the added height of this layer can easily make available a substantial increase in the positive potential vorticity inherent in the negatively buoyant plumes.

Ertel's [1942] potential vorticity theorem—composed of a synthesis of the conservation laws for mass, momentum, and energy in a single mathematical statement—has received wide application in diverse dynamical studies ranging from oceanographic to ionospheric. For our purposes, we are attempting to synthesize into a single mathematical statement the exchange of information among many dynamical regimes, it is instructive to consider that potential vorticity is closely aligned to the concept of angular momentum. Each volley of upward-propagating internal gravity waves that serves to dislodge a negatively buoyant plume of high potential vorticity is thus creating a discrete "packet" of cyclonic angular momentum capable of significantly influencing tropospheric dynamics.

This unifying concept brings us full circle, back to Planck's discovery of the quantum nature of radiation and Schrödinger's wave equation that describes the exchange of angular momentum among complex systems. As was mentioned in the introduction, Planck began his derivation with an equation descriptive of a simple harmonic oscillator. Although the oscillating element was originally conceived of as an electron embedded in an electromagnetic field, contemporary physicists emphasize that different sets of elementary particles represent varying "resonance channels" or patterns of quantum connectivity.

Not only is this mathematical format appealing when it comes to describing the complexity of the solar-biospheric-climate gestalt, but even the interim idea put forth by Bohr that an atom consists of discrete energy levels seems relevant to the highly interactive atmospheric and oceanographic domains. However, what constitutes an "electron" in the present study?

If we recall that "sunspots" consist of intense convective disturbances in the solar atmosphere, then the ubiquitous nature of convective processes in all dynamical domains reminds us that they alone can change the identity of a system at its most fundamental level. The atmospheric analogue for an equation describing a simple harmonic oscillator:

$$\ddot{\tau} + \frac{f|\zeta|}{\rho \Gamma_n} \dot{\tau} + \frac{g}{T_r} |\gamma_d - \gamma| \tau = 0 \qquad (1)$$

states that the zeroth, first, and second-order time derivatives of τ—or the temperature difference realized in a convective event which is 100% efficient in creating condensate—forms the mathematical basis for describing super-efficient information exchange within atmospheric dynamics. In addition to the diabatic or quantum signal represented by τ, other variables in (1) include the density and temperature (p, T_r), the gravitational acceleration (g), the dry adiabatic and environmental lapse rates (γ_d, γ), and the specific heat at constant pressure (C_p). The term $f|\zeta|$ refers to the position of the buoyant parcel relative to its initial entropy state, where the parcel's change of entropy is dependent upon its change of potential temperature, and C_p.

If the coefficient of τ is negative, then the buoyant parcel will be dislodged from its original constant entropy level; if positive (stable case), the parcel will oscillate about its original position at a frequency given by

$$\nu = [(g/T_r)|\gamma_d - \gamma|]^{1/2} / 2\pi$$

Like Planck, we use a change of entropy plus specific frequencies to define information exchange among macroquantum domains. We thus avoid a spatial description of the hydrothermodynamic field by simply noting how an elemental oscillator (convective event) behaves when embedded in a field characterized by a particular stability. This amounts to saying that the convective event is a discrete element of radiative flux which obeys Stefan-Boltzmann's law for a blackbody [see *Paine and Prusinger*, 1979].

We have been addressing the negatively buoyant, stratospheric phenomena in much of the above discussion. Let us now shift our attention toward the equally important, positively buoyant (tropospheric) events that accompany the macroquantum information exchange process. The atmospheric analogue to Planck's law descriptive of the energy (U) of the radiant fields states

$$U = \frac{h\nu}{e^{h\nu/kT} - 1} \qquad (2)$$

This analogue substitutes C_p for k (Boltzmann's constant), while the tropospheric value for Planck's constant (h^*) has empirically been found to equal 21×10^{16} erg s. (The energy (E) which may be dislodged from a discrete layer whose potential is defined by h^* is determined by a specific frequency of oscillation (ν).) In a severe convective storm generating internal gravity waves, a typical ratio for the exponent ($h^*\nu/C_pT$) is 0.025, where the scale height of the troposphere (10 km) must be exceeded by the upward propagating waves to achieve information transfer. This height is effectively compared against the horizontal distance (400 km) of a "bowed" frontal inversion. Such a density discontinuity or interface serves as a wave guide for external gravity (or so-called "shallow-water") waves organizing coherent bands of severe convective activity.

The advantage of employing quantum physics to explain highly nonlinear, multiscaled information exchange between complex systems is its elegant simplicity: for example, satellite pictures may present a bewildering view of warm water eddies breaking away from the Gulf Stream or developing cumulonimbi in a thunderstorm ensemble that defy a detailed Newtonian-Cartesian solution. Yet the quantum approach tells us that the energy entering or leaving a fundamental domain must appear at a specified frequency (or its harmonics) uniquely determined by γ, γ_d, p, and T_r if there is to be a fundamental change in the system's identity.

The quantum view of climate supports the concept first entertained in the content of the Laplace formalism; namely, warm water bodies function like "tuning forks" and thus are able to act as a coherent wave and energy source for the atmospheric medium, provided the appropriate middlevel stability criteria are met and the proper "hammer" is present. The 11.2-year sunspot cycle is apparently one such instrument where the interactivity with earth's heat reservoirs (including the O_3 layer) occasionally rings loud and clear in the physics of climate. Other possibilities come to mind; for example, the highly variable energy input associated with solar flares or cosmic ray emissions; all have the potential of exciting resonant states of activity at decipherable levels of the atmosphere when viewed from the quantum paradigm.

Alternatively, El Chichón in the quantum world view appears much like a "high energy" climate event whose rare cascade of continuing interactivity may have had the ability to dramatically alter one or more of the normal pathways that constitute the rich matrix of solar-terrestrial connectivity. After a short review of the postulated role of solar-modulated incoming UV radiation, we will address the question of mankind's ability to alter earth's climate via the absorption of outgoing infrared radiation by increased amounts of carbon dioxide. Once again, the quantum climate hypothesis is found to offer new insight for scientists seeking to gauge the influence of the ongoing exponential rise in the burning of fossil fuels on the effects of changing earth's albedo through the melting of sea ice or deforestation.

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Cover. Auroral imagery from the DMSP-F6 satellite. The two photographs are from the DMSP Optical Linescan System, taken on consecutive northern hemisphere polar passes on January 18, 1983. The dawn aurora is in the lower part of the photos, with midnight to the left and dusk at the top. The overlayed contours show bremsstrahlung X ray intensity as measured by the scanning SSB/A X ray sensor provided by The Aerospace Corporation's Space Sciences Laboratories. (See Eos, p. 170, May 3, 1983.) (Photo courtesy D. J. Gorney, P. F. Mizera, and W. A. Kolasinski.)

Conclusions: Factoring in the Influence of Mankind

A simple cause-and-effect concept of climate has assumed that the greater the solar input, the more heat will be available to the atmosphere. This is correct, provided one is careful to distinguish the particular level that is heated and also its ultimate effect. Because ultraviolet radiation represents only 14% of the net solar energy received by earth, most of which is absorbed above 16 km, its primary importance is one of controlling stratospheric stability. When there is greater incoming UV radiation, the enhanced production of ozone provides an important diabatic heat source to the stratosphere. This added stability, in turn, could conceivably suppress the number and intensity of major tropospheric storms unless overridden by other factors.

Such storm suppression would effectively decrease the upward flow of sensible and latent heat into the lower atmosphere. Paradoxically, we therefore see that the net effect of greater UV radiation—heating only a small, but dynamically important portion of the middle atmosphere—is therefore to chill the weather-producing troposphere. Alternatively, prolonged absence of sunspots, such as in the 17th century's Maunder Minimum or the earlier Spörer Minimum, could effectively exhaust many of the heat reservoirs by contributing to greater climate instability and storminess. Presumably such a dynamical sequence, as evidenced in expanded and ice cores, would first provide a "rush" of diabatic heat input into the troposphere, followed by longer episodes of abnormal chilling. The nonlinearity of the postulated triggering mechanism enables the slow buildup of stored solar energy arising from the net incoming radiation to be released over relatively short periods of time. This, in turn, yields a commensurately greater response factor to the physics of climate. From a biological perspective, large short-term thermal fluctuations can also extract a severe evolutionary toll, as evident from the reported loss of an estimated 17 million seabirds on Christmas Island during the 1982–1983 El Niño [*Eos*, April 5, 1983, p. 131].

The self-organizing and self-regulating capacity of the oceans, atmosphere, and biosphere working in consort to maintain earth's life support system is receiving increasing attention. In keeping with James Lovelock's thesis examined in *Gaia* [*Lovelock*, 1979], I have chosen the interdisciplinary concern over CO_2 buildup to illustrate further how quantum climate physics accentuates the crucial roles being played by trace gases like O_3 and CO_2. Ozone is subject to chemical sources and sinks (e.g., NO_x) that are themselves subject to modification by anthropogenic activity; however, for brevity, the CO_2 problem—although far from being "simple" because it, too, changes in proportion to the varying backdrop of biospheric activity, ocean temperature, and circulation—will suffice to demonstrate another potential application of the quantum paradigm.

In prior discussion, we have stressed stability variations associated with the diabatic effects of water vapor, a rather "prolific" trace gas that constitutes anywhere from 0 to 4% of the troposphere by total volume. From 1958 to 1980, atmospheric carbon dioxide content has risen from 315 to 338 parts per million [*MacCracken and Moses*, 1982], an increase of 8% in 22 years. The current scientific consensus estimates that CO_2 may have increased by 25% since 1850 and is likely to double its 0.0315% volume content before A.D. 2100. Additional CO_2 at the projected level of increase has the capacity to absorb greater amounts of the returning longwave radiation, creating the so-called "stratify" (or correctively influenced) greenhouse effect. Essentially linear models of climate have extrapolated that at least a 2°C global warming and consequent melting of polar sea ice and rise of sea level could result from this effect within the next century.

However, the quantum climate hypothesis shifts our attention away from any linear or direct climate influence by asking a two-part question: First, how is mankind's release of solar energy stored in fossil fuels over geological time linked to the terrestrial mechanism of storing and releasing heat and CO_2 within the hydrosphere? Second, and perhaps most importantly, is it possible that CO_2-induced infrared absorption will exert an influence on climate primarily through alterations of stability rather than simple bulk heating? If this is so, it is crucial that we determine whether lower stratospheric stability—seemingly capable of being profoundly altered over at least a short 2 or 3 year period by a single major volcanic eruption—is subject to a longer term CO_2 influence.

In the emerging quantum view on the nature of climate, the sun-earth system appears like a symphony being played by a multitude of instruments. These instruments are defined against a widely varying backdrop of space and time, a fact that precludes a rigorous mathematical description of their interactivity when studied from the Newtonian paradigm. The quest of the climate theorist is not only to describe the individual instruments, but also to yield practical advice on how these components behave as a collective and highly complex system.

Article (cont. on p. 428)

Article *(cont. from p. 427)*

Appendix: The Laplace Transform

The basis of this method is the transformation defined by

$$F(s) = \int_0^\infty f(t)e^{-st}\,dt = Lf \qquad (A1)$$

The function $F(s)$ is the Laplace transform of $f(t)$, and the operator L that transforms f into F is the Laplace transform operator. This formula represents a superposition of exponential functions, e^{-st}, where the superposition is over time t and s represents frequency.

To duplicate three solar cycles from 1954 to 1987, we begin with

$$\int_0^\infty e^{-(s+c)t}f(t)\,dt = \int_0^\infty e^{-st}e^{-ct}f(t)\,dt$$

and note that this is equivalent to

$$F(s+c) = L[e^{-ct}f(t)] \qquad (A2)$$

where

$$F(s) = L[f(t)]$$

A property related to equation (A2) is

$$L[f(t-c)] = e^{-cs}\,L[f(t)] \qquad (A3)$$

where the constant $c \geq 0$ and $f(t) = 0$ for $t \leq 0$. Equation (A3) can be used to obtain the transform of an admissible periodic function $f(t)$ of period $T > 0$. We can then state the interesting identity

$$f(t) = f_0(t) + f(t-T) \qquad t \geq 0 \qquad (A4)$$

whose graphical interpretation is given in Figure 5.

Acknowledgments

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News

Leveling in Earthquake Area

The National Geodetic Survey (NGS) is performing first-order geodetic leveling in the Coalinga, Calif., area. The project, which is being funded by the U.S. Geological Survey (USGS), is intended to measure vertical height differences associated with recent Coalinga earthquakes.

The largest of the earthquakes occurred on May 2 with magnitude 6.5 (Richter scale). More than 1,500 aftershocks have followed, including two on May 8, which were magnitude 5.5. Damage estimates exceeded $30 million (see *Eos*, May 26, p. 387). No loss of life was reported, but 1,000 residents were displaced.

At the request of the USGS, NGS Mobile Field Party G-36 immediately began field reconnaissance and bench mark recovery operations. The first-order leveling, which totals approximately 50 km, will be completed by the end of June. Where possible, new leveling will follow lines of leveling previously performed in 1969 and 1972. This will provide an indication of vertical height differences during the intervening years caused both by subsidence in the area from man-made causes and by vertical height differences associated with the earthquakes. The data will be analyzed by NGS and USGS. Reports of the analyses should be written in July or August.

STARE System Looks at ULF Magnetics

STARE (Scandinavian Twin Auroral Radar Experiment) has analyzed magnetospheric ultralow frequency (ULF) waves in the ionosphere since 1977. STARE data analysis recently discussed by J. J. Singer of the Air Force Geophysics Laboratory, Massachusetts, includes new explanations of the oscillations that occur in the shell structure of the geomagnetic field (*Nature*, May 5, 1983, p. 15).

The ULF pulsations (periods from tens of seconds to 10 min) were thought to be standing hydromagnetic waves that resonate on geomagnetic field lines. Singer describes these waves as having the unusual character of periods that increase as a function of latitude. This phenomenon may clarify the nature of their source and of the characteristics between individual oscillating geomagnetic shells. Singer notes the argument supporting the standing-wave theory as being the consistency of the wave periods with the time it takes Alfvén waves to travel along geomagnetic field lines between ionospheric reflection boundaries.

The STARE system, which is composed of two coherent pulse Doppler radars located near Malvik, Norway, and Hankasalmi, Finland, measures the ionospheric electric field by making the radar signals reflect from electrostatic waves excited in the E region of the auroral zone. The radar pulses scattered by the electrostatic waves are Doppler shifted in frequency as a result of the electron $E \times B$ drift velocity. Analysis of the scattered pulses yields values of amplitude and direction of the electric field in the region of overlap of the two radars. STARE has relatively high spatial (202 km) and temporal (20 s) resolution. The system is very beneficial for these measurements in that it takes data over a large area (400^2 km) simultaneously.

Recent STARE observations described by Singer include a number of transient events whose pulsation showed an increase in period with latitude. These events are apparently toroidal eigenmode oscillations, which are east-west magnetic field perturbations. Because of Hall currents in the ionosphere, the oscillations were observed simultaneously as north-south perturbations by a ground-based magnetometer. The observations are interpreted as being a simultaneous occurrence of oscillations from separate magnetic shells. Thus it was shown that magnetic field lines on adjacent shells can oscillate at different frequencies, implying only weak coupling between the lines. These measurements were possible because the STARE system is free of ionospheric screening effects. Comparison with ground measurements may yield information about the attenuation and screening phenomena.—*PMB*

VLBI Observations

From the centers of quasars calculated to have velocities 10 times greater than that of light—the Einsteinian constant of the universe—astronomers are finding explanations of Doppler effect red shifts of emission. Very long baseline interferometry (VLBI) arrays have been used to examine the cores of seven known radio sources in space that are characterized by superluminal velocities, and a significant amount of knowledge has been gained about red-shift phenomena of plasma sources. Milliarcsecond resolution of VLBI techniques allows observers to examine in detail central structures of radio sources.

According to a discussion of observers at the recent superluminal workshop held at the Jodrell Bank Observatory, U.K., February 1983, "The last six years have brought a great increase in reliability of results, particularly because of the use of VLBI arrays. . ." (*Nature*, April 28, 1983). This reliability has resulted in a compilation of properties of radio-source core structures. The steep frequency-shifted radio spectrum of a superluminal structure is apparently caused by rapidly extending plasma jets. The discussion provides the following explanation of a relativistic jet: ". . . a relativistically moving stream of plasma emanating from the core. . . [which]. . . is identified with the base of the jet. . . . The 'moving' components are shocks or plasmons moving down the jet, which point toward the observers in the case of superluminal sources" (*Nature*, April 28, 1983). The idea is that illusions of Doppler effect red shifts can be produced by high-energy physical phenomena other than simple velocity effects. Even in the case of a source moving away from an observer with a relative velocity less than the speed of light, an illusion of superluminal velocity results because the angle of view is small ("because the observer's view of the early part of the motion is delayed with respect to the later parts, and hence the apparent duration of the motion is shortened" (*Nature*, April 28, 1983)).

Another effect that can cause illusory red shifts is the so-called "Doppler favoritism" phenomenon, which is a similar "small angle" effect that results in an enhancement of flux density. Curiously, superluminal sources have arc second jets located only on one side of the nucleus, as well as the central milliarcsecond jets. These jets could be "Doppler favorites" or they could simply be unexplained properties of radio sources.

The research on these unusual radio sources also examines the small-angle phenomena. There are theories that relate the observed strengths of quasars to their line-of-sight angles; sources with weak radio cores and double outer lobes are at large angles and vice versa. A number of problems in explaining "classical double" radio quasars have arisen from recent measurements.

There are many ideas emerging on how to explain the observations. Some observations can be explained if the jets are released from the cores as a sort of plasma spray, the angle of view being a function of visual collimation of a portion of the jet. Other observations seem to require the existence of single, narrow jets.

Certain broad theory explanations include the origin of galactic phenomena. According to one such theory discussed at the workshop: ". . . the Galactic Center, Seyfert galaxies, and quasars are interpreted as reflecting just two intrinsic parameters—the mass of the central compact object (black hole) and the accretion rate into it" (*Nature*, April 28, 1983).—*PMB*

Year of Oceans?

John V. Byrne, administrator of the National Oceanic and Atmospheric Administration (NOAA), has proposed that 1984 be observed as the Year of the Oceans. The year should be devoted to defining and clarifying the U.S.'s ocean and coastal goals and "rallying the support to achieve them," Byrne recently told oceanographers attending the Coastal Zone '83 gathering in San Diego, Calif.

"Today we see ferment in ocean and coastal concerns," Byrne said. Among the examples he cited was the proclamation issued by President Reagan on March 10 declaring an exclusive economic zone within 200 miles of the coast where the United States will exercise jurisdiction for the purposes of exploring, exploiting, conserving, and managing natural resources (*Eos*, June 7, 1983, p. 402). In addition, "legislation has been introduced to define the outer continental shelf, deep seabed minerals, ocean thermal energy, marine pollution, fisheries, and other oceanic concerns," Byrne said. "In both houses of the U.S. Congress, legislators are considering bills that would establish a National Oceans Policy Commission," he added.

NOAA's administrator also urged that state and private organizations share in the effort to provide strong marine programs. "Only with active participation and guidance by the private and state sectors can the federal government discharge its responsibilities efficiently."

Earth Dating by Ion Probe

The ion microprobe is an instrument that is finally coming into its own in isotope and trace-element analysis of particulate mineral samples. The idealized ion microprobe would be able to analyze sample volumes of less than one cubic micrometer. The analysis would include major-element bulk composition and the chemical formula of the mineral being analyzed. More essential, the analysis would also contain trace-element composition and isotopic abundances because the ion microprobe employs a mass spectrograph as its analytical device. Ideally then, an investigator would be able to obtain major-, minor-, and trace-element data and be able to date geologically a small portion of a mineral crystal instantaneously and simultaneously. That this ideal is being realized today is evident in the recent results of W. Compston and colleagues at the Australian National University. Compston et al. have dated zircon crystals from Mount Narrayer in western Australia at 4.2 billion years, the oldest date of a terrestrial sample (*New Scientist* May 19, 1983). How these dates will stand up vis à vis the oldest whole-rock dates (3.8 billion years for samples from West Greenland) remains to be seen. The Mount Narrayer date is for single grains extracted from a sedimentary rock. The Greenland whole-rock dates were obtained by more conventional, though nonetheless state-of-the-art, mass-spectrometry techniques.

The concept of the ion microprobe probably dates back to the early 1940's RCA patents of J. Hillier. R. Castaing revived the ideas about electron and ion microprobes less than a decade later in his thesis research at the University of Paris, and he built prototype instruments. It has taken two to three decades since then for the promise of the ion microprobe to be realized. Quantitative isotope analysis of single crystal surfaces on a point-by-point basis may have far-reaching applications in broad fields of geophysics. Isotope ratios for age-dating purposes will be very powerful, as will isotope and trace-element studies.

The new zircon dates are based on uranium and radio-decay product ratios. To be an accepted milestone in the studies of dating the earth, the rocks from which the zircon crystals were derived must be known. The implication is that the zircons originated from rocks whose radio clocks were set 4.2 billion years ago. Rather than a clearly documented geological observation, the new results are more in the form of a portent of things to come. Scientists will find it exciting when there is hard evidence that the earth is as old as the moon.

The ion microprobe represents a combination of the complex technologies of electron-ion (static field) optics, surface-ion physics, and the intricacies of the mass spectrograph. It would appear evident that this combination has begun to function in the results of Compston and, indeed, of others who are pioneering this great advance.—*PMB*

Brace To Grace Wheaties?

You have until July 15 to vote to put an AGU Fellow on the Wheaties cereal box.

William F. Brace, head of the Massachusetts Institute of Technology's (MIT) Department of Earth and Planetary Sciences, has been nominated as MIT's outstanding athlete in the current Wheaties nationwide "Search for Champions" contest.

Ballots for the Wheaties contest are available only on Wheaties boxes. The top 50 finishers will receive one dollar per ballot for the affiliated nonprofit organization—the MIT Community Service Fund in Brace's case. From the 50, a committee will select six to be pictured on Wheaties boxes. The charities of the six finalists will receive an additional $1,000.

In the last 11 years, Brace has run in 50 marathons and in two 50-mile races. Among his many triumphs, he was second in his age group in the 1980 Pike's Peak Marathon. He officiated with Brian Bonner at the AGU Fun Run at the 1980 Fall Meeting and was one of the organizers of the race at the 1981 Fall Meeting.

For additional information about the contest, contact MIT graduate students Kaye Shedlock (telephone: 617-253-5810) or Carol Hundwerker (telephone: 617-253-4040). Brace was nominated for the contest by the Green Building Track Club and the MIT Community Service Fund in Cambridge, Mass.

IRAS Discovers Second Comet

Astronomers sifting through data sent to earth by the Infrared Astronomical Satellite (IRAS) have discovered an extremely faint comet that came within 210 million km of our sun on January 20. This is the second comet to have been sighted by the satellite in a two-week period.

Comet IRAS (1983F) was found by the orbiting telescope on May 13 (GMT) and was confirmed by ground-based observers on May 19. The comet is one million times fainter than comet IRAS-Araki-Alcock, which was discovered simultaneously by IRAS and the two amateur astronomers for whom the comet is named. IRAS-Araki-Alcock passed Earth May 11.

Many faint comets that had previously passed through the inner solar system without being noticed now may be able to be sighted by IRAS in its year-long sky survey, IRAS astronomers say.

IRAS is a joint project of the U.S. National Aeronautics and Space Administration, the Netherlands Space Agency, and the United Kingdom's Science and Engineering Research Council.

Streamflows at Record Highs

Streamflow was reported well above average in more than half the country during May, with flows at or near record levels for the month in 22 states, according to the U.S. Geological Survey (USGS), Department of the Interior.

USGS hydrologists said that above average flow was reported at 98 of the 173 USGS key index gauging stations used in their monthly check on surface- and ground-water conditions. High flows were most prevalent in the Mississippi River basin states and in the east, with the exception of Maine, South Carolina, and Georgia. Below-average streamflow occurred in the Pacific northwest and in small scattered areas in Colorado, Kansas, Texas, and Minnesota.

The combined flow of the three largest rivers in the lower 48 states—Mississippi, St. Lawrence, and Columbia rivers—was 46,000 billion gallons during May. These three large river systems, which include the flow of the Missouri and Ohio rivers, account for runoff from more than half of the conterminous United States and provide a quick, useful check on the status of the nation's surface-water resources.

Ground-water measurements were generally average or above average throughout much of the country, reflecting the above-normal precipitation patterns of the past several months.

Working in cooperation with federal, state, and local officials, USGS hydrologists routinely collect information on the quantity and quality of the nation's surface- and ground-water resources at more than 45,000 sites across the country. The highlights of May water-resources conditions are as follows:

1. The Big Five Rivers. Mississippi River at Vicksburg, Miss., 1,034 bgd, 88% above average and 35% above the April flow; Columbia River at The Dalles, Ore., 269 bgd, 3% below average, but 84% above last month's flow; Ohio River at Louisville, Ky., 215 bgd, 153% above average and 46% above the April flow; St. Lawrence River near Massena, N.Y., 182 bgd, 1% above average and 2% above last month's flow; and Missouri River at Hermann, Mo., 135 bgd, 127% above average, but 9% less than the April flow.

2. New York. In upper New York state, water from Great Sacandaga Lake spilled over the Conklingville Dam for the first time in its 53-year history. The overflow lasted 10 days, pushing the Hudson River to its highest flow levels since 1936.

3. North Carolina. Wet conditions continued throughout North Carolina during May, and several major streams were well above average for the fourth straight month. Flow of the French Broad River at Asheville, N.C., averaged 1.9 bgd, 39% above average for May, and flow of Contentnea Creek at Hookerton, N.C., averaged 479 million gallons a day, 53% above average. Ground-water levels in the state were generally 2–6 feet above the long-term averages for May and were 1–6 feet higher than the levels this time last year.

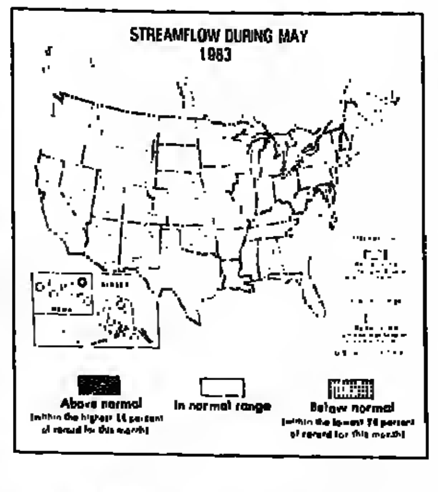
4. Iowa. Wet conditions persisted in much of Iowa. Flows of the Des Moines River at Fort Dodge, Cedar River at Cedar Rapids, and Nishnabotna River near Hamburg have been well above average now for 9 consecutive months. The Des Moines and Cedar rivers set new record high flows for the month. Flow of the Des Moines River at Fort Dodge averaged 5.1 bgd during the month, the highest May flow in 51 years of record.

5. Minnesota. Streamflow conditions were varied throughout Minnesota. Streams in the northeastern part of the state were below average, while in the southwestern corner of the state, streams were above average. Flow of the Rainy River at Manitou Rapids, Minn., averaged 4.9 bgd during May, 58% below average. In the south, flow of the Minnesota River at Jordan, Minn., averaged 10.5 bgd, 195% above average, the second highest May flow in 49 years, and the eighth straight month that flow of this stream has been well above average.

6. Utah-Nevada. In the western United States, heavy rains and sharply warmer temperatures melted record-deep mountain snowpack in Utah and Nevada, resulting in torrential runoff, severe floods, and mudslides. Utah's land-locked Great Salt Lake rose more than 7 inches in May, to its highest level since 1924 and more than 3 feet higher than the level at this time last year.

7. Washington. Streamflow through most of Washington state was below average during May. Flow of the Skykomish River near Gold Bar, Wash., for example, averaged 3.2 bgd, 27% below average. This is the second straight month that the flow on this stream has been well below average.

8. California. Wet conditions prevailed across the entire state during May. All five of the key USGS index gauging stations in California reported flows that were well above average for the month. Flow of Arroyo Seco near Pasadena, Calif., averaged 41 million gallons a day, the highest May flow in 69 years of record. In southern California, water levels in the key wells in Los Angeles and Santa Barbara counties were all above average. The level in the key index well near Cuyama, in Santa Barbara County stood at 40 feet below the land surface, almost 74 feet above the long-term average, and highest in 33 years of record. (Map courtesy of the *U.S. Geological Survey*.)



Books

Recent Trends in Hydrogeology, 1982

T. N. Narasimhan (Ed.), *Spec. Pap. 189*, Geol. Soc. of America, Boulder, Colo., 448 pp., 1982, $32.

Reviewed by Mary P. Anderson

Recent Trends in Hydrogeology consists of a set of papers presented during a birthday party on February 9, 1979. The birthday party, or, more properly, the symposium, was convened to honor a distinguished hydrogeologist, Paul A. Witherspoon, on his 60th birthday. Many of the papers were written by Witherspoon's former students as well as by his current colleagues at the Lawrence Berkeley Laboratory and the University of California, Berkeley.

A preface by the editor (T. N. Narasimhan) provides an introduction to the volume and short commentaries on each of the 23 papers as well as ideas on probable future directions in hydrogeology. According to the preface, the purpose of the symposium was "to attempt a reasonable coverage of the important facets of hydrogeology" and "to provide a global picture of hydrogeology" where hydrogeology is defined as "the discipline concerned with those geologic processes that are influenced by water," presumably meaning subsurface water. Hence, the material covered in this volume is broad, ranging from topics traditionally associated with hydrogeology, such as well hydraulics and regional flow system analysis, to more exotic subjects, such as geothermal resources and induced seismicity. As a result, only those with the most catholic interests will read all 23 papers.

However, all hydrogeologists are likely to relish the excellent critical review articles on contaminant migration in saturated unconsolidated material (R. W. Gillham and J. A. Cherry); statistical characterization of heterogeneous aquifers (S. P. Neuman); and flow test evaluation of fractured reservoirs, in which A. C. Gringarten presents a synthesis of methods, drawn from the geotechnical, geological, and petroleum literature, for evaluating the transmission properties of fissured formations. These three papers represent state-of-the-art summaries on three of the "hottest" new areas of hydrogeologic research. Most hydrogeologists will also be interested in R. A. Freeze's synthesis of groundwater-stream relationships using deterministic and stochastic concepts; J. E. Gale's compilation of hydraulic conductivity measurements for fractured rock, and perspectives on regional flow system analysis by Bredehoeft, Back, and Hanshaw.

Of more specialized interest are T. N. Narasimhan's insights into numerical modeling techniques as well as his ideas on the physics of unsaturated flow and D. C. Helm's paper on land subsidence. Others will be interested in papers on analytical solutions, well test instrumentation, the relationship between well loss and skin effect, groundwater problems in mines, and physical properties of porous material. There is also an informative summary of past and current studies involving storage of energy in the form of relatively hot or cold water in aquifers (Tsang and Hopkins), as well as a lengthy paper by T. D. Snow investigating the causes of induced seismicity upon reservoir filling, and four papers on various aspects of geothermal resources. In addition to the papers on fractured rocks, there are two other papers addressing problems associated with disposal of high-level radioactive waste in a subsurface repository: an overview by S. N. Davis and a paper on isotopic dating of groundwater in crystalline rock by P. Fritz. Last, there are a number of units conversion tables at the end of the book.

From a 1983 perspective, the current trends in hydrogeology that are accurately reflected in this collection of papers presented in 1979 are contaminant migration, flow through fractured rock and other aspects of nuclear waste isolation, and stochastic processes. It could be argued that the other papers, which when taken individually are not really representative of strong trends in hydrogeology, when taken as a whole do reflect another current trend: the increasing interaction between hydrogeologists and those in related disciplines such as petroleum engineering, mining engineering, and soil mechanics. However, it is more significant that the volume does not contain any major papers addressing one of the strongest current trends in hydrogeology, deciphering and quantifying chemical reactions in the subsurface. There are sections on hydrogeochemistry in the lengthy review paper by Gillham and Cherry and in the paper by Bredehoeft et al. There also is a fairly specialized paper examining the chemical problems involved in the reinjection of geothermal brines, but there are no general review papers on chemical reactions in the subsurface. Perhaps the absence of papers on this subject suggests that questions related to hydrogeochemistry are some of the most difficult to address and even more difficult to answer.

The book measures 8½ x 11 inches in size, and the text is presented in two columns per page. The pages were produced from camera-ready copy generated by a word processor; figures and tables are well done throughout. While the print is crisp and clear, the lines of type are single spaced, causing a lot of material to be packed onto each page, which may cause some eye strain with prolonged reading. The price may seem a bit steep, but at less than 8 cents a page, the book should be considered a bargain.

Mary P. Anderson is with the Department of Geology, University of Wisconsin-Madison, WI 53706.

High-Precision Earth Rotation and Earth–Moon Dynamics: Lunar Distances and Related Observations

O. Calame (Ed.), D. Reidel, Hingham, Mass., xix + 354 pp., 1982, $125.

Reviewed by John M. Wahr

The last decade or so has seen the practical development of a number of high-precision, space-related geodetic techniques, specifically, lunar laser ranging (LLR), satellite ranging, and very long baseline interferometry (VLBI). One consequence has been an enlarged and improved data base available for studies of lunar motion and earth rotation.

The impact on lunar studies has been particularly striking. The vast improvement in lunar positioning data provided by the LLR experiment has revived interest in the previously lethargic business of modeling the lunar orbit and librations (librations are rotational displacements of the moon about its center of mass). Several numerical and analytical mod-

els of the orbit and librations have been developed over the past few years. Numerical models, constructed by numerically solving appropriate differential equations, are generally more accurate than existing analytical models and are, in principal, better suited to removing the effects of lunar motion from the LLR residuals. On the other hand, results from numerical models are less amenable to physical interpretation, and so analytical models continue to receive attention. Analytical models are particularly useful in trying to understand the lunar librations, both because of the possibility of excited free librations and because the dynamical behavior of the moon during the forced librations is not completely understood.

So far, the new geodetic techniques have had less of an effect on earth rotation studies. Rotation data from traditional optical astrometry are still competitive at periods of a few months and longer. The most pronounced advantage of the new techniques is their ability accurately to determine changes in rotation (i.e., pole position and rotation rate) at periods between a few days and a few months. But it appears that most of the geophysically useful signal occurs at longer periods.

Both lunar motion and earth rotation results derived from the new techniques were discussed at the International Astronomical Union (IAU) Colloquium 63, held in Grasse, France, during May 22–27, 1981. This book constitutes the proceedings of that colloquium. It will probably be of little interest to people who have no working knowledge of the field, primarily because, in common with other conference proceedings, the 37 contributions here are short and not designed for a general audience. (There are some arguable exceptions, most notably a summary by J. Henrard of existing analytical models of the lunar orbit; a presentation by D. S. Robertson and W. E. Carter describing results from VLBI; and contributions from J. Dickey, H. Fliegel, J. Williams, and C. Yoder describing the Jet Propulsion Laboratory (JPL) reduction of LLR data.)

But an additional factor here is that the subject has not yet developed to the point where results can be routinely interpreted in terms of geophysical or lunar processes. The reader expecting to learn anything generally useful about the earth or moon will be disappointed. On the other hand, the book does give a representative picture of the current state of the subject. And although the field is rapidly evolving, the problems and techniques described here will probably be around for some time.

It is not possible to provide more than a brief description of the contents of these proceedings. (A more complete discussion can be found in Byron Tapley's report on the colloquium published in *Eos*, January 26, 1982, p. 132.) Most of the earth rotation work presented here is concerned with the data analysis. There are contributions from groups at JPL, the Massachusetts Institute of Technology, and the Centre d'Études et de Recherches Géodynamiques et Astronomiques describing their current efforts at reducing the LLR data. There are discussions of the analysis of VLBI data and of data obtained from ranging to the GPS and Navy Navigation satellites. (Two presentations describing results from ranging to the LAGEOS satellite are presented here by abstract only.)

There are also several attempts to combine and compare rotation data derived from competing techniques. Other earth rotation contributions include a description of Chinese efforts in the field, discussions of the 1980 IAU nutation series, and a description by J. Williams and W. Melbourne of a possible future problem associated with adopting fixed precession and equinox corrections. The one case here where the results permit geophysical interpretation, a study by Langley et al. relating variations in the earth's rotation rate to changes in atmospheric angular momentum, is represented in these proceedings by abstract only.

Most of the lunar motion studies are concerned with modeling the lunar orbit. Most important is probably a description by J. Chapront and M. Chapront-Touzé of their improved analytical model that includes the effects of planetary perturbations. Other orbital studies include quantitative comparisons of numerical and analytical models and discussions of the orbital effects of earth tides and general relativity. The one attempt to use the observed orbital results to learn new physics is a study by T. C. Van Flandern of a possibly changing gravitational constant, but it is represented here only by its abstract.

Lunar libration results are more immediately accessible to useful physical interpretation than are the lunar orbital studies but are not nearly as well documented in these proceedings. D. H. Eckhardt describes an improved analytical libration model that includes the planetary and earth figure perturbations. The other libration-related contribution, a general review by R. W. King, is represented here by abstract and bibliography only. Other lunar and orbit-related studies are discussions of selenodetic reference frames and a development by R. Broucke and W. Presler of a small parameter expansion of the disturbing function for the three body problem.

John M. Wahr is with the Department of Physics and the Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309.

Isotope Studies of Hydrologic Processes

E. C. Perry, Jr., and C. W. Montgomery (Eds.), Northern Illinois University Press, 118 pp., 1982, $25.

Reviewed by D. I. Siegel

During the past decade, the study of environmental isotopes has become an increasingly powerful tool toward understanding hydrologic processes. The present book, a selection of twelve papers presented at the 1980 Midwest American Geophysical Meeting, is a useful addition to the literature of isotopic methods used in hydrologic studies and will be of particular value to those interested in groundwater flow system analysis and groundwater chemistry.

The papers deal with the stable isotopes of oxygen and hydrogen in water; carbon in bicarbonate; sulfur in sulfate and sulfide; and the radioisotopes of uranium, hydrogen, and radium. The first paper, by the editors, provides a brief but succinct introduction on isotopic processes. Of particular interest to this reviewer are papers by Perry et al. and Desaulniers et al., who explain isotopically light groundwater ($\delta_{18}O$ about 5‰ lighter than modern recharge water) in Illinois bedrock aquifers and clayey Pleistocene deposits in south-central Canada as Pleistocene recharge during colder climates. Desaulniers et al. used ^{14}C to demonstrate that the isotopically lighter waters in the Pleistocene deposits could be up to 13,000 years B.P.

Not all hydrogeologic systems are so relatively well defined isotopically. Fritz and Frape show that Ca-Na-Cl brines, found in bedrock on the Canadian Shield, are isotopically heavy, and plot above the "meteoric water line" on a $\delta_{18}O$ versus δD diagram. The genesis of these waters is unknown, but probably related to rock/water interaction.

Rock/water interaction in the active Ngawha geothermal system in New Zealand is discussed in detail by Blattner who shows that a positive shift in $\delta_{18}O$ in the geothermal waters can be nonuniquely explained by interaction of reservoir rock with both meteoric and magmatic waters. Similarly, a paper by Krothe on sulfur isotopes in groundwater systems on the Ogallala Formation, southwestern Kansas, and the St. Louis limestone in southern Indiana illustrates the difficulty in differentiating among isotopic sources, sinks, and modifying geochemical processes.

The only paper on isotopes in surface water, by Sklash and Farvolden, is mainly a summary of their previous work, and restates the hypothesis that a major portion of stormflow in small watersheds may be groundwater. The proposed cause of accelerated groundwater discharge during storms is the growth of transient groundwater "ridges" or mounds near the stream. Although this hypothesis may be considered provocative to some hydrologists, studies of hydraulic gradients near lake shores also have shown the existence of transient groundwater mounds after large storms.

Papers on radioisotopes are equally varied in content. A paper by Michel et al. presents gamma ray spectroscopy as a method to determine activities of $_{226}Ra$ and $_{228}Ra$. Uranium and radon concentrations in aquifers in east-central Minnesota are described by Lively and Morey, and Gilkeson and Cowart related uranium disequilibrium to redox potential along a groundwater flow path in northeastern Illinois. Tritium was used with stable isotope data by Stewart and Downes to identify different water masses in a spring in New Zealand.

Isotopic Studies of Hydrologic Processes is a book that presents some interesting work through case studies as well as information of a more general nature for the scientist interested in learning how to use isotopes as a tool in hydrologic research. The cost of the book, however, may limit widespread distribution. A soft cover edition would perhaps have been more fitting.

D. I. Siegel is with the Department of Geology, Syracuse University, Syracuse, NY 13210.

Classified

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For further information, call toll free 800-424-2488 or, in the Washington, D. C., area, 462-6903.

POSITIONS AVAILABLE

Postdoctoral Position in Igneous Petrology/Northern Illinois University. Position is for one or two years. Position involves collection and analysis of geochemical data on basic plutonic rocks, but time will be available for writing and research on independent projects. Experience with probe, XRF, INAA, and geochemical modeling of igneous rocks is preferred. Candidates willing to teach an introductory petrology course during spring semester will be given preference. Starting date will be August or September, 1983, depending on availability of candidate. Application deadline is July 15, 1983, although search will continue until position is filled. Send resume and names of three referees to: Professor J.H. Berg, Acting Chair, Department of Geology, Northern Illinois University, Dekalb, IL 60115.

Northern Illinois University is an affirmative action/equal opportunity employer.

Meteorologist/Lead Scientist/Manager. To lead a group of meteorologists and programmers working on a variety of tasks related to meteorological modeling for weather forecasting, satellite data assimilation methods and mesoscale meteorology.

Ph.D. in meteorology, experience in assimilation/objective analysis, weather forecasting models, and related computer programming/numerical techniques required. Vector-computer and supervisory experience desirable.

Please send resume to: K.F. Klenk, Systems and Applied Sciences Corporation, 5809 Annapolis Road, Hyattsville, Maryland 20784, or call (301) 699-3954.

An equal opportunity employer.

Postdoctoral Position in Atmospheric Chemistry and/or Cloud Physics/Georgia Institute of Technology. Recent Ph.D. scientists interested in the development of theoretical models to study the chemistry and physics of precipitation are invited to apply to the Georgia Institute of Technology.

The salary is $18,000/year; period of appointment is one-two years. Applicants should send vita and statement of research interests and the names of two references to: Professor W.L. Chameides, School of Geophysical Sciences, Georgia Institute of Technology, Atlanta, GA 30332.

GEORGIA INSTITUTE OF TECHNOLOGY IS AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER.

Research Scientist/Space Plasma Physics, University of Iowa. A research position is available in the Department of Physics and Astronomy, The University of Iowa, for theoretical and interpretative studies of waves in space plasmas. Specific emphasis is on theoretical investigations of wave-particle interactions in planetary magnetospheres and in the solar wind. These investigations are to support the interpretation of data being obtained from spacecraft projects such as Dynamics Explorer, International Sun Earth Explorer and Voyager. The applicant must have a Ph.D. with good qualifications in plasma physics theory and should have some experience in the interpretation of space plasma physics data.

Send a resume and the names of three references familiar with the applicant's work to: D.A. Gurnett, Department of Physics and Astronomy, The University of Iowa, Iowa City, Iowa 52242, telephone 319-353-3527.

The University of Iowa is an affirmative action/equal opportunity employer.

Research Positions for Mathematical Physicists. Applications are invited for several research positions at the Center for Studies of Nonlinear Dynamics, La Jolla Institute, beginning summer 1983. Current research involves work on nonlinear wave-wave interactions, acoustic, optical, and radio wave propagation in random media, and fluctuation phenomena in the statistical mechanics of chemical and geophysical systems. Physicists and applied mathematicians who are interested in working on problems of the above type should send resumes and arrange for three letters of recommendation to be sent to Dr. Stanley Flatte, Director, CSND, La Jolla Institute, 8950 Villa La Jolla Drive, Suite 2150, La Jolla, California 92037.

La Jolla Institute is an equal opportunity/affirmative action employer.

Research Associate/Petrography-Petrology. To join a research effort aimed at understanding the condensation history of the solar system by mineralogical, chemical, and isotopic studies of tiny inclusions in primitive meteorites. Applicant need not have previous experience with meteorites but should be a superb petrographer, skilled in the use of the SEM and electron probe. Successful candidate will be dedicated, productive, an effective communicator both orally and in writing, and will have Ph.D. in hand. Vacancy expected in late summer or early autumn 1983.

Send resume and names of three references to: L. Grossman, Department of the Geophysical Sciences, University of Chicago, 5734 S. Ellis Avenue, Chicago, IL 60637.

The University of Chicago is an equal opportunity/affirmative action employer.

Hydrogeologist. Converse Consultants is seeking a staff or project level hydrogeologist for investigations involving groundwater quality and supply, waste disposal, mineral and energy development and geotechnical projects. Las Vegas-based, will serve primarily in the southwestern U.S. Opportunity for interaction with an expanding staff of professionals in six regional offices. Excellent salary and advancement potential.

Minimum requirements are an advanced degree in geology plus two to five years experience involving such areas as aquifer testing and modeling, well and well field design; quantitative evaluation of groundwater flow, contractor supervision. Good communication skills are essential. Additional training or experience in geophysics and hydrology is desirable. Contact Dr. Robert F. Kaufmann, Principal Geologist, Converse Consultants, Inc., 4056 S. Spencer Street, Suite 120, Las Vegas, NV 89109.

University of Colorado, Boulder, Geochemist Position. Geochemist with active research program, stable isotopes, radioactive isotopes, and/or trace elements is being sought for a joint appointment in the Department of Geological Sciences and the Cooperative Institute for Research in Environmental Sciences (CIRES) of the University of Colorado. The one-half time position within the Department of Geological Sciences is tenure track at the assistant or associate professor level with a starting salary of $12,000–$15,000 for the academic year. Teaching load will be half that of full-time faculty. The position within CIRES will be as a Fellow with appropriate office and laboratory space. One-half academic year salary will be guaranteed by CIRES for two years as the departmental rate, after which incumbent must generate his/her CIRES salary from external sources. Incumbent may augment salary further by generating three months of summer salary from contracts and grants, and consulting.

Applicants with experience, publications, and/or movable existing research equipment preferred. Preferred starting date would be January 1, 1984. Closing date for applications is October 1, 1983. Applications should include statement of research and teaching interests, experience, a full vitae, and four letters of reference.

Apply to: Professor Charles Stern, Chairman, Geochemist Search Committee, Department of Geological Sciences, Campus Box 250, University of Colorado, Boulder, CO 80309.

The University of Colorado is an equal opportunity/affirmative action, Section 504 employer.

Research Scientist for International Ground Water Modeling Center. A position is immediately available for a Research Scientist in the International Ground Water Modeling Center. IGWMC is an international information center for ground water modeling. It organizes and operates a clearinghouse for ground water models, conducts a program in applied research on ground water modeling, and publishes the Ground Water Modeling Newsletter.

The successful applicant will have a Ph.D. in Civil Engineering/Hydrology with a background in quantitative ground water hydrology, including chemistry of ground water. The person must have at least one (1) year experience in modeling flow and transport processes and should be acquainted with related recent research. A solid background in numerical and stochastic analysis is required.

Incumbent will perform the applied research programs of the Center, including exploring modeling needs and research trends, and technical evaluation of models, and will be involved in the continuous updating of programs, and in handling information requests.

The annualized salary for the position is $28,000 for a 37.5 work week, typically from 8:30 a.m. to 5:00 p.m.

Interested applicants must include their number 67860 and social security number in a response by July 28, 1983 to:

Indiana State Employment Service
10 North Senate Avenue
Indianapolis, Indiana 46204
Attention: W.F. Shepherd

An equal opportunity employer.

Argonne National Laboratory/Chemistry Division. An immediate postdoctoral position is available for atmospheric chemistry studies based on mass spectrometric analysis of the stable isotopic composition of atmospheric trace gases. Problems include source budgets and temporal variations of atmospheric trace gases and determination of atmospheric OH free radical concentrations using stable isotope tracers. Experimental techniques involve preparation of gas samples derived from trace gases using carrier gas trap systems with cryogenic and chemical separation methods and precision mass spectrometric analysis. Send resume to: Mr. Walter McFall, Personnel Division, Box D-CHM-80, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.

An equal opportunity employer.

Postdoctoral Position/Naval Postgraduate School. The Ocean Turbulence Laboratory has available a postdoctoral position for a person interested in the analysis and interpretation of oceanic turbulence data. The tenure is for one to two years. The successful candidate should have a Ph.D. in physical oceanography and although experience with turbulence data is preferable it is not essential. The opportunity for involvement in data gathering expeditions is also available.

Resumes can be sent to Dr. R.G. Lueck, Code 68Lu, Naval Postgraduate School, Monterey, CA 93940.

An Equal Opportunity/Affirmative Action Employer.

Research Professor in Marine Geoscience/University of Rhode Island. The Graduate School of Oceanography invites applications for a research professorship in Marine Geoscience whose salary and rank are negotiable. Preference will be given to candidates who have clearly demonstrated abilities and interest in, but not necessarily limited to paleomagnetism. The position is funded by contracts and grants, however the research professor holds full faculty rights in addition to other benefits. The paleomagnetic facility at GSO is fully equipped, fully operational and oriented towards rapid measurement of large numbers of soft sedimentary samples. Applications are now open for the position which will become available about January 1, 1984.

Send letters of application, resume, and names and addresses of three professional references to: Roger L. Larson, Graduate School of Oceanography, University of Rhode Island, Narragansett, Rhode Island 02882.

An affirmative action/equal opportunity employer m/f.

Scientist I/National Center for Atmospheric Research. To work under the supervision of the reactive gases project leader. Will plan and oversee major elements of field experiment; develop analytical techniques appropriate to field and laboratory use; and analyze, interpret and model the data gathered. Requirements include: Ph.D. in atmospheric science or equivalent knowledge and skill, with a strong basic knowledge of atmospheric chemical and chemical kinetics; skills in research demonstrated by publications; skills and experience in analytical chemistry of aerosol and gaseous and aqueous atmospheric substances; skill in design, testing and implementation of chemical analytical techniques; skill in development of computational models, parameterization of atmospheric, physical and chemical processes, and application of numerical and statistical techniques. Scientist I appointments are for term of up to three years. Individual may be appointed to the next higher level of scientist in accordance with the UCAR Scientific Appointment Policy. Salary: $25,814 to $37,722 annually. To apply contact: Esther Balzon, (303) 494-5151 extension 581 or send resume and list of publications to NCAR Employment, P.O. Box 3000, Boulder, CO 80307.

An equal opportunity/affirmative action employer.

Physical Oceanography/University of Rhode Island. A postdoctoral research associate position is available starting October 1, 1983 for studies of tropical processes in the Pacific. The research involves the collection and analysis of data relating to the dynamic topography and zonal pressure gradients of the equatorial current systems as part of a long-term study of ocean influences on climate. Submit resume and professional references by August 15, 1983 to: Dr. D. Randolph Watts, Marine Research Associate II Position, UNIVERSITY OF RHODE ISLAND, P.O. Box 357, Kingston, Rhode Island 02881.

An affirmative action/equal opportunity employer m/f.

Iowa State University of Science and Technology, Department of Earth Sciences/Research Associate: Electron Microprobe. The Department of Earth Sciences invites applications for a Research Associate position as an electron microprobe specialist. The appointment will be a fully funded, permanent, twelve-month position. Salary will be commensurate with qualifications.

Primary duties are the operation and maintenance of a fully automated microprobe with WDS and EDS capabilities and the supervision of associated laboratory facilities. Additional duties include instruction of research personnel in instrument operation. Ample opportunities exist for conducting collaborative and independent research involving the microanalysis of geological materials.

Applicants should have a M.S. degree in a science or engineering field, or equivalent experience, and experience with electron beam instrumentation. Persons with a working knowledge of WDS and EDS spectrometers and the accompanying computer operations and experience analyzing geological samples will be preferred applicants.

Application deadline is July 31, 1983. Later applications will be accepted if the position is not filled. Applications should include a complete resume, a statement of background and interests, copies of publications and names of at least three references. Applications should be sent to:

Bert E. Nordlie
Department of Earth Sciences
Iowa State University
253 Science I
Ames, Iowa 50011

Iowa State University is an equal opportunity/affirmative action employer.

Faculty Position in Marine Geology/University of Maryland, Center for Environmental and Estuarine Studies (UMCEES). Horn Point Environmental Laboratories of UMCEES invites applications for a tenure track research faculty position (rank open) for a marine geologist. The successful candidate will join a growing physical/geological oceanography program, so applicants with a wide range of interests will be considered. Opportunities exist for interdisciplinary research with biological and chemical oceanography programs. Although some preference will be given to candidates with interests in estuarine and continental shelf sedimentological processes, the primary criterion for selection is the ability to develop a strong research program. The closing date for applications is August 1, 1983. Curriculum vitae, description of research interests and list of references should be sent to:

Dr. Larry G. Ward
Chairman, Search Committee
UMCEES
Horn Point Environmental Laboratories
P.O. Box 775
Cambridge, Maryland 21613.

The University of Maryland is an affirmative action/equal opportunity employer.

Professor of Meteorology/University of Maryland. The Department of Meteorology at the University of Maryland, College Park, invites applications for a tenure line Professorship. We seek a well-established, highly recognized scientist with an outstanding international reputation in atmospheric and oceanic modeling and applications. We propose the establishment of a center to study the interactions of atmosphere, ocean and land processes and their impact on climate variability, and in particular to study the feasibility of short term climate predictions. The applicant should be qualified to lead such a Center, plan its projects, organize its activities, and bring to the University the necessary resources to attract outstanding scientists to the Center and to carry out its research functions. Salary is negotiable. To apply, please send a complete vitae and the names of references to the Chairman, Search Committee, Department of Meteorology, University of Maryland, College Park, MD 20742. Applications received by 22 July 1983 will receive full consideration.

The University of Maryland subscribes to policy of equal educational and employment opportunity. The University of Maryland is required by Title IX of the Education Amendments of 1972 not to discriminate on the basis of sex in admission, treatment of students or employment.

Chairman—Department of Geological Sciences, Wright State University. The Department of Geological Sciences invites applications for the position of chairman, to be appointed September 1984. We seek a dynamic individual with administrative talent and an appreciation for research and practice-related educational activities. Rank is at the full professor level and no restrictions have been placed on areas of specialization. The department is active with 12 faculty and an emphasis on professional practice, yet maintaining a firm commitment to basic research.

Send a letter of application, curriculum vitae and names of three references to:

Chairman, Search Committee
Department of Geological Sciences
Wright State University
Dayton, OH 45435.

Wright State University is an affirmative action/equal opportunity employer. Closing date for the position is October 31, 1983.

University of Arizona/Faculty Position. The Department of Hydrology and Water Resources invites applications for a faculty position in hydrology with a specialty in groundwater chemistry. Candidates must have training and/or professional experience in hydrogeology and must have demonstrated abilities in the quantitative aspects of the topic. Appointment will be at the level of an assistant or associate professor. Interested individuals should obtain further information from:

Professor Stanley N. Davis
Chairman, Search Committee
Department of Hydrology and Water Resources
University of Arizona
Tucson, Arizona 85721
602-621-3131.

The University of Arizona is an affirmative action/equal opportunity employer.

Marine Research Associate II. Analyze and interpret time series of vertical acoustic travel time and bottom pressure. Prepare progress reports and scientific manuscripts on these results. Assist in planning experiments and participate in scientific cruises. Ph.D. in physical oceanography plus experience in computer programming with times series applications in FORTRAN. Submit application and resume by August 15, 1983, to: Dr. D.R. Watts, Marine Research Associate II Position, University of Rhode Island, P.O. Box 357, Kingston, Rhode Island 02881.

An affirmative action/equal opportunity employer m/f.

STUDENT OPPORTUNITIES

Graduate Assistantships/Howard University. Howard University in Washington, D.C., offers a new graduate program for the M.S. degree in geoscience; made possible by a grant from the Gulf Oil Company. Areas of specialization are field geology/geophysics, geochemistry, and meteorology/hydrology with remote sensing. Some stipends and assistantships are available. Potential students should write to Dr. Eric Christofferson, Department of Geology and Geography, Howard University, Washington, D.C. 20059.

SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

Ground Based Airglow and Aurora Optical Science Facilities Workshop. U.S. airglow and auroral scientists interested in ground based optical observations have formed a facilities definition group. Their main purpose is to assess the need and to plan for the development of modern state-of-the-art facilities to further the investigation of the major scientific problems within the field. The group selected Dr. Lyle Broadfoot (CNL-Tucson) as chairman, Dr. G. Romick (U of A, Fairbanks) as secretary, Dr. W. Hanson (Univ. of Texas/Dallas), R. Eather (Boston College, Chestnut Hill), G. Hernandez (NOAA-Boulder), M. Torr (Utah State-Logan), P. Hays (U of Michigan-Ann Arbor), W. Sharp (Univ. of Michigan-Ann Arbor) and R. Roble (NCAR-Boulder) members of the organizing committee.

An initial workshop has been scheduled for August 1, 2, and 3, 1983 in Logan, Utah. The format will consist of invited speakers to review chemistry and dynamics of the stratosphere, mesosphere and thermosphere; chemistry, modeling, spectroscopy, and applications to the magnetosphere and auroral physics; and current ground based facilities, sites and instrumentation used in interferometry, spectroscopy, photometry and imaging in airglow auroral studies.

The intent of this workshop is to initiate the development of a working paper describing the scientific goals, the implementation policies, and the description and location of the major facilities needed within this field. Also to be included will be a discussion of the need for enhanced communication within this group of scientists; the possibility of more formal organization; and the rationale for an annual topical meeting.

A complete agenda will be distributed to all scientists on the current mailing list. Anyone wishing to obtain further information can contact any member of the organizing committee. All scientists interested in this area of aeronomy are invited to attend. Specific details on the workshop will be available and distributed by the first week in July.

Meetings

Announcements

Penrose Conference

The Geological Society of America Penrose Conference entitled "Melanges of the Appalachian Orogen" will be held June 23–30, 1984, in Newfoundland, Canada. The conference will focus on the origin, significance, and characteristics of melange in distinct geological settings. The importance of careful field observations in deciphering melange terranes will be emphasized. As such, much of the conference will center around in situ field discussions; Newfoundland offers a good cross section of the Appalachian orogen and its melanges.

The conference will begin on Newfoundland's west coast with excursions to melanges associated with the assembly and emplacement of Ordovician allochthons onto the ancient continental margin of North America. Next on the agenda is the Burlington Peninsula, where scientists will be able to examine polydeformed and metamorphosed melanges associated with the deformed easterly edge of the ancient continent; the melange of imbricated ophiolite that comprises the suture zone between continental and oceanic terranes; and associated olistostromes deposited immediately after the destruction of the margin. The final field area will be the controversial Cambro-Ordovician Dunnage Melange, located in the easternmost part of the ancient oceanic terrane, and the Silurian olistostromes of New World Island.

Interspersed with these field trips will be formal and informal discussions on the origin, significance, and correlation of melanges along the Appalachian orogen; comparisons of Appalachian melanges with those of other orogens; and general melange topics such as modes of origin and structural and stratigraphic characteristics.

For more information, contact, before February 1, 1984, Brenna E. Lorenz, Department of Earth Sciences, Memorial University of Newfoundland, St. Johns, Newfoundland A1B 3X5 Canada. Lorenz, Nick Rast (in the geology department at the University of Kentucky, Lexington), and Harold Williams (in the earth sciences department at the Memorial University of Newfoundland, St. John's, Newfoundland) are the convenors.

Ophiolites

The working group on Mediterranean Ophiolites will hold its second annual meeting at the Istituto di Mineralogia, Petrografia e Geochimica, in Florence, Italy, on December 15–17, 1983.

Focusing on oceanic tectonics and metamorphism, the meeting will consider the structural and metamorphic history of ophiolites during the period between their formation and their involvement with the continental crust. Similar events in present-day oceanic settings may also be discussed.

Abstracts, not to exceed one typed page, should be submitted by September 30, 1983, to Giovanni B. Piccardo, Istituto di Mineralogia, Petrographia e Geochimica-Università, via La Pira 4, 50121 Firenze, Italy. All abstracts and papers, whether or not accepted for presentation at the scientific session, will be published in a special issue of *Ofioliti*.

Hydrologic Forecasting

The American Water Resources Association (AWRA) symposium entitled "A Critical Assessment of Forecasting in Western Water Resource Management" will be held in Seattle, Wash., on June 11–13, 1984. The symposium will focus on the science of hydrologic and demand forecasting and its relationship and significance to operational, planning, and policy decisions by both the public and the private sector in the western United States.

A session on the operation of water resource systems will focus on the use of very short-term hydrologic and demand forecasting for the improved operation of existing systems. Among the topics to be included are short-term river flow/river forecasting techniques; long-term (monthly to seasonal) runoff forecasting techniques, and methods to incorporate forecasts and forecast uncertainty in system operation policies.

Another session, on capital program planning and implementation, will focus on the planning of capital facility expansion for water resource systems. Among the topics to be covered are long-range and very long-range water demand forecasting techniques; evaluating trends and uncertainty of social, economic, and technological factors, and their relationship to water demand forecasting; and methods for evaluating the economic loss from failing to meet demand growth.

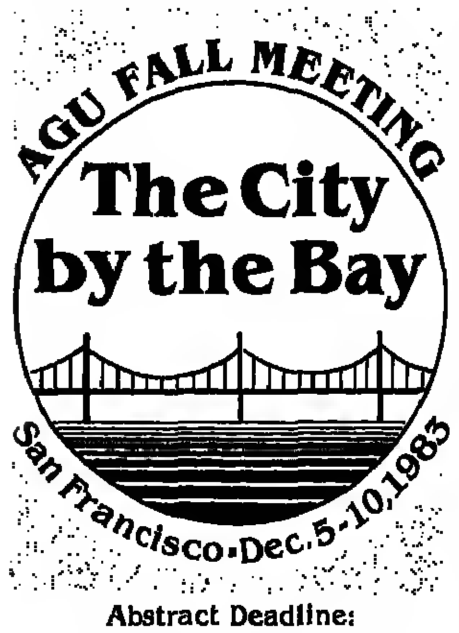
Abstracts, not to exceed 200 words, should be sent no later than November 1, 1983, to the general chairperson, Gary R. Minton, President, Resources Planning Associates, 113 Lynn Street, Seattle, WA 98109.

AWRA Conference

The American Water Resources Association (AWRA) will conduct its Nineteenth Annual Conference and Symposium on October 9–13, 1983, in San Antonio, Tex.

The conference on analysis and management of land drainage and flood waters will feature 20 technical sessions on such topics as planning for stormwater runoff; nonpoint source water pollution problems; stormwater quality, floodplain management, and flood control planning; water resources computations by microcomputer; and remote sensing as a planning tool. Fifteen technical sessions on regional and state water resources planning will deal with such topics as changing roles in water resource financing, federal versus state versus regional responsibilities, water importation or interbasin transfer issues, and state and regional groundwater management issues.

For preliminary program and registration information, contact Kenneth D. Reid, Executive Director, AWRA, Suite 220, 5410 Grosvenor Lane, Bethesda, MD 20814.



Abstract Deadline: September 14

Call for Papers

Abstracts must be received at the AGU office by 5:00 P.M. on September 14. Late abstracts (1) may be summarily rejected by program chairman, (2) may not be published in advance of the meeting, or (3) if accepted, will be charged a $25 late fee in addition to the regular publication charge.

The 1983 Fall Meeting of the American Geophysical Union will be held in San Francisco from December 5–10 at the Cathedral Hill and Holiday Inn/Golden Gateway hotels. Blocks of rooms are being held at the Cathedral Hill, the Holiday Inn/Golden Gateway, the San Franciscan, the Holiday Inn/Civic Center, and the Grosvenor Inn. Corresponding authors will be sent housing and registration forms. In addition, the forms will be published in *Eos*.

General Regulations

Abstracts may be rejected without consideration of their content if they are not received by the deadline or are not in the proper format. Abstracts may also be rejected if they contain material outside the scope of AGU activities or if they contain material already published or presented elsewhere. Only one contributed paper by the same first author will be considered for presentation; additional papers (unless invited) will be automatically rejected.

Only AGU members may submit an abstract. The abstract of a nonmember must be accompanied by a membership application form (with payment) or it must be sponsored by an AGU member.

There is a publication charge of $40 ($30 if prepaid) for each abstract. If the first author is a student, the publication charge is $20. Both invited and contributed papers are subject to the publication charge. Prepayment of the publication charge can save money. Send a check for $30 ($15 for students) with your abstract. The abstract must be received at AGU by September 14 to avoid an additional $25 charge.

AGU will acknowledge receipt of all abstracts. Notification of acceptance and scheduling information will be mailed to corresponding authors in late October.

Abstracts

The abstract page is divided into two parts: the abstract itself and the submittal information. Follow the instructions for both carefully. Please use a carbon ribbon to type the material, and do not exceed the maximum dimensions (11.8 cm by 18 cm) of the abstract. Abstracts that exceed the noted size limitations will be trimmed to conform.

The meeting program will be prepared by photographing the abstracts exactly as they are received. Use the model abstract to prepare the final version. Submission of an abstract for an AGU meeting is presumed to carry with it permission for AGU to reproduce the abstract in all editions of *Eos* and in the programs and reports relating to the meeting. It is also presumed to permit the free copying of those papers. Although *Eos* is a copyrighted journal, authors are not requested to transfer copyright. Copyright, where it exists, will be reserved by the authors.

Submittal Information

Numbers refer to the items in the submittal block on the sample abstract.

1. Title of meeting.
2. Identification (only members may submit an abstract; this includes invited authors): Type identification number of one member author (ID number is the line consisting of four letters followed by the six digits; see member's mailing label on *Eos* or journals), or, if no author is an AGU member, type the ID number of the member sponsor (sponsor's name must also appear on the abstract at the end of the author portion). If no ID number is given, a membership application and dues payment must accompany the abstract. Call AGU (800-424-2488 or 462-6903 if you are in the Washington, D.C., area) immediately if you need an application.
3. Corresponding address: Give complete address and phone number of author to whom all correspondence (acknowledgment and acceptance letters) should be sent. Abbreviate as much as possible.
4. Section of AGU to which abstract is submitted (use the following letter abbreviations): A (Atmospheric Sciences); G (Geodesy); GP (Geomagnetism and Paleomagnetism); H (Hydrology); O (Ocean Sciences); P (Planetology); S (Seismology); SA (Aeronomy); SM (Magnetospheric Physics); SC (Cosmic Rays); SS (Solar and Interplanetary Physics); T (Tectonophysics); V (Volcanology, Geochemistry, and Petrology); U (Union).
5. Type title of special session (if any) to which submittal is made.
6. Indicate your preference for a particular kind of presentation by one of the following letters: O, oral; P, poster. The chairman may assign you to either of these types of presentation in order to fit his program plan.
7. Percent of material previously presented or published, and where.
8. Billing information:

(*a*) Complete billing address if other than the corresponding address (item 3 above).

(*b*) If purchase order is to be issued, indicate number upon submittal of abstract. Invoices returned to AGU because of insufficient billing information will be assessed an additional charge of $10.00.

(*c*) If a student member is the first author, the student publication rate is applicable. Indicate that the student rate is applicable.

(*d*) If prepaid, enter amount enclosed.

9. Indicate whether paper is C (contributed) or I (invited). If invited, list name of inviter.

Poster Sessions

A large, centrally located meeting room will be set up for poster presentations. Experience from recent AGU meetings and from other scientific societies has shown that a poster presentation, while more demanding of the author, can provide a superb opportunity for comprehensive discussions of research results. Some sections are organizing poster sessions on specific topics, and contributed papers on these subjects will automatically be scheduled as posters. In other sections it may be necessary to assign papers to poster sessions even though the authors requested oral presentation.

Presenters of poster papers are reminded that a poster exhibit requires careful preparation. Figures and text will be scrutinized in detail, and authors must be prepared to discuss the contents of their papers in depth. Under these conditions, well-prepared figures and concise logical text are essential.

Program Committee

Meeting Chairman H. Frank Eden, NSF
Atmospheric Sciences (A) Ronald Taylor, NSF
Geodesy (G) William Sjogren, Jet Propulsion Laboratory
Geomagnetism and Paleomagnetism (GP) Subir K. Banerjee, University of Minnesota
Hydrology (H) Dennis P. Lettenmaier, University of Washington, Seattle
Ocean Sciences (O) Dave Cutchin, Scripps Institution of Oceanography
Planetology (P) Richard J. Terrile, Jet Propulsion Laboratory
Seismology (S) Robert J. Geller, Stanford University
SPR Aeronomy (SA) Raymond G. Roble, NCAR
SPR Cosmic Rays and Solar and Interplanetary Physics (SS/SC) Miriam A. Forman, SUNY, Stony Brook
SPR Cosmic Rays and Solar and Interplanetary Physics (SS/SC) Bruce T. Tsurutani, Jet Propulsion Laboratory
SPR Magnetospheric Physics (SM) Michael Schulz, Aerospace Corp.
Tectonophysics (T) Raymond F. Jeanloz, University of California, Berkeley
Volcanology, Geochemistry, and Petrology (V) Peter W. Lipman, USGS

Special Sessions

Union
Polar Research

Geomagnetism and Paleomagnetism (GP)
Applications of Paleomagnetism to Tectonics of the Western United States
Electrical Conductivity of the Crust and Upper Mantle—Field Methods and Laboratory Measurements (in cooperation with the Committee on Mineral Physics)
Problem Solving With Rock Magnetic Techniques—Case Histories

Hydrology (H)
Glacier-Ocean Interactions (jointly sponsored with Ocean Sciences)
Instream Flow Requirements for Fish: Methodologies, Implementation, and Impacts
Multivariate Modeling of Hydrologic and Other Geophysical Time Series
Searching for More Physically Based Extreme Value Distribution in Hydrology
Statistical Procedures for Estimation of Flood Risk at Gauged Sites
Symposium on Optimization Techniques for Managing Groundwater and Stream-Aquifer Systems
The Orinoco and the Amazon—Hydrology, Sedimentology, Geochemistry, and Ecology of Large Tropical Rivers
Transport Processes of Excessive Sediment Loads
Treatment of Evapotranspiration, Soil Moisture Evolution, and Aquifer Recharge in Watershed Models
Water Quality Analysis of Impoundments

Ocean Sciences (O)
California Current
Chemical Tracers and Global Circulation Modeling
Diagenesis in Deep Sea Drilling Cores
El Niño of 1982–83
Geochemistry of Estuaries
Geochemistry of Hydrothermal Plumes in Vicinity of Mid-Ocean Ridges
HEBBLE
MANOP
Ocean-Glacier Interactions (jointly with Hydrology)
Rossby Waves and Eddies in the Eastern Parts of Ocean Basins
Sedimentation Patterns in Tectonics in Active Continental Margins (jointly sponsored with Tectonophysics)
Sub-Sealed Disposal of Nuclear Wastes: Site Assessment
The Response of the Upper Ocean to Very Strong Wind

Seismology (S)
Evolution of Oceanic Lithosphere (cosponsored by Tectonophysics and Volcanology, Geochemistry, and Petrology)
Rio Grande Rift (cosponsored by Tectonophysics and Volcanology, Geochemistry, and Petrology)
Lateral Heterogeneities in the Mantle
Tomograph

SPR: Aeronomy (SA)
EUV-VU Airglow
Lower Thermosphere–Upper Mesosphere

SPR-Cosmic Rays (SC)
IMP 7 & 8: Correlative Studies Over the Solar Cycle, Including Correlative Studies With Other Spacecraft and/or With Ground Data (poster session) (cosponsored by SPR: Interplanetary Physics and SPR: Magnetospheric Physics)
IMP 7 & 8: (cosponsored by SPR: Interplanetary Physics and SPR: Magnetospheric Physics)

SPR-Magnetospheric Physics (SM)
Aurora and Substorms (poster session)
Comparative Planetary Magnetospheres and Comparative Auroral Phenomena
Geomagnetic Tail and Boundary Layer (poster session)
Magnetospheric Currents and Fields (poster session)
Numerical Simulation of Space Plasmas (poster session)
Special Call for Papers on all Subjects
Waves, Instabilities, and Turbulence in Space Plasmas (poster session)

SPR-Solar and Interplanetary Physics (SS)
AMPTE Theory and Predictions
Solar Wind Interactions With Comets, Venus, and Titan

Tectonophysics (T)
Active Tectonics
Franciscan Geology of the San Francisco Bay Area: The Nanoplate Tectonics of the AGU Fall Meeting Site
Tectonics and Sedimentation in Active Continental Margins (jointly sponsored by Ocean Sciences)

Volcanology, Geochemistry, and Petrology (V)
Calderas and Associated Volcanic Rocks (Krakatau Centennial)
Cascades Volcanism and Implications for Geothermal Resources
Ocean-Ridge Basaltic Volcanism (Laki Bicentenial)
Structure and Dynamics of Hawaiian Volcanoes

Other Special Sessions

Mineral Physics
If one of the following fields is covered in the broadest sense, regardless of the section to which your paper is submitted, please add on your abstract "For Mineral Physics Session" under number 5 of the submittal information: (1) physical measurements on minerals, (2) calorimetry, (3) high-pressure mineralogy, (4) defect structure studies, (5) mineral and solids equations of state, (6) quantum mechanics of solids, (7) spectral mineralogy, or (8) electrical measurements on minerals.

Session Highlights

Geodesy (G)

Geodesy will be hosting special sessions this fall on the results from the earth-orbiting satellite LAGEOS (Laser Geodynamics Satellite). Summaries will be presented by the major investigators dealing with earth rotation, station coordinates and baselines, ocean-tide parameters, mass and gravity field of the earth, and evolution, and geophysical interpretation. There will also be sessions devoted to crustal dynamics, gravity data analysis, modeling of tidal effects, timing, and precision orbit determination.

Hydrology (H)

Glacier-Ocean Interactions (jointly sponsored by Hydrology)

A special session on glacier-ocean interactions will be convened jointly by the Ocean Sciences and Hydrology sections. Papers are solicited that address topics on the interaction processes between glaciers or glacial ice in the oceanic environment. Topics of interest include but are not limited to calving of tidewater glaciers, thermodynamic interaction between marine ice shelves or icebergs and sea, sediment oceanic modification, and iceberg drift. Invited papers will give overviews of recent studies and new developments in this area. Abstracts, in standard AGU format, should be submitted no later than August to either of the session cochairmen: Andrew G. Fountain, Project Office—Glaciology, 850, USGS, 1201 Pacific Avenue, Tacoma, WA 98402, or Edward G. Josberger, USGS, University of Puget Sound, Tacoma, WA 98416. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Instream Flow Requirements for Fish: Methodologies, Implementation, and Impacts

Recent federal and state legislation has guaranteed that fish production must be considered in the development of water resources. This renewed interest in fish management will affect significantly, in many situations, the amount of water available for consumptive water uses. Numerous techniques have been suggested for establishing instream flow requirements, ranging from hydraulic models for streamflow to fish habitat models. Less research has been directed toward other significant issues of instream flow maintenance such as evaluation of the economic impacts of these instream requirements on other users, their economic benefits, and flow estimation techniques that indicate the frequency with which these requirements affect other users.

Papers are solicited that explore techniques used to establish instream flow requirements, the economic and physical interactions of the requirements among water users, and procedures that incorporate low flow frequency estimates into requirement analysis. Papers addressing the conceptual framework for establishing instream flow requirements, model calibration and verification, case studies, and related topics are also welcome. Abstracts, in standard AGU format, should be sent by August 31 to Richard Palmer, Department of Civil Engineering, FX-10, University of Washington, Seattle, WA 98195. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Multivariate Modeling of Hydrologic and Other Geophysical Time Series

This special session is sponsored by the Surface Runoff Committee of the Hydrology section. The purpose of this special session is to bring together individuals from different disciplines to discuss the state of the art and new developments of stochastic description and/or modeling in time and/or in space of multiple time series of hydrologic and geophysical phenomena.

Quite a number of models and modeling techniques have been proposed for representing univariate and multivariate time series with applications in hydrology and geophysics. However, even when modeling single time series there are still a number of unsolved or controversial questions that merit further studies and discussions. This situation is compounded when dealing with multiple time series. As the models attempt to incorporate more statistical features of the historical time series, the number of parameters increases, the mathematics of the model becomes cumbersome, the identification and estimation procedures are more difficult, the testing of goodness of fit of the models is more complex, and the problem of how to deal with various types of uncertainties often becomes unmanageable.

Possible topics for this special session include multivariate model identification techniques, parameter estimation procedures, model testing and validation techniques, discrete and continuous models, ARMA and non-ARMA models, Gaussian and non-Gaussian models, models with periodic and aperiodic parameters, aggregation and disaggregation techniques, sensitivity analysis, modeling of uncertainties, Bayesian and non-Bayesian techniques, models for transfer of information, models for detection of trends, and models for data generation and forecasting.

Abstracts, in standard AGU format, should be sent by August 15 to Jose D. Salas, Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009. Additional information can be obtained from J. D. Salas (telephone: 303-491-8460 or 303-491-6047).

Searching for More Physically Based Extreme Value Distribution in Hydrology

There is a great need in hydrology for extreme value distributions that incorporate more of the physics of the underlying processes. For floods, this will allow the hydrologist to make better use of the scarce data which is usually available for streamflows and to attack the problem of ungauged catchments with a better approach than regional regressions.

A special afternoon session will be dedicated to this problem. The topics to be covered will be scale and similarity in flood frequency response, derived distributions for ungauged catchments, inhibition phenomena of flood peaks, etc.

A comparison session in the afternoon will discuss the most recent statistical techniques for estimating flood risk. A panel discussion chaired by John Schaake will follow the afternoon session in which new avenues of research on both areas of flood estimation will be presented.

Both sessions are under the auspices of the Surface Runoff Committee of the Hydrology section. For more information on this session, please contact Juan B. Valdes, Room 48-331, Massachusetts Institute of Technology, Cambridge, MA 02139 (telephone: 617-253-2117). The original of the abstract and two copies, in standard AGU format, should be sent to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Statistical Procedures for Estimation of Flood Risk at Gauged Sites

During the last 5 years, research has produced many new and improved statistical techniques for estimating flood risk and various qualities of the flood-flow distribution at gauged sites. This session will review these new ideas and *Bulletin 17* as revised in September 1981. Topics should include advantages of regionalization, regional skewness, empirical Bayes estimators, probability weighted moments and the Wakeby distribution, measurement error and its impact, nonparametric procedures, and the use of historical flooding information. A companion session in the afternoon will examine the search for more physically based extreme value models in hydrology. The day will close with a special panel discussion chaired by John Schaake, Jr. Abstracts, in standard AGU format, should be sent by August 15 to Jery R. Stedinger, Hollister Hall, Cornell University, Ithaca, NY 14853. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Symposium on Optimization Techniques for Managing Groundwater and Stream-Aquifer Systems

Groundwater has been a largely unmanaged resource. Consequently, many areas are encountering problems of excessive local drawdown, reduced streamflows, and groundwater contamination. Currently, groundwater simulation models are used to explore management alternatives to solve these problems. In the future, combined use of groundwater simulation and optimization techniques of mathematical programing may prove to be a tremendous aid to managing groundwater resources. Such management models may be used to manage aquifer pumping and injection systems, to optimally allocate water in a stream-aquifer system, to manage groundwater quality, or to inspect the influence of institutions upon patterns of regional groundwater use.

This symposium on optimization techniques in groundwater management is sponsored by the Groundwater Committee. Abstracts, in standard AGU format, should be sent by August 31 to Steven M. Gorelick, U.S. Geological Survey, Mail Stop 21, 345 Middlefield Road, Menlo Park, CA 94025. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009. More information can be obtained by contacting Steven M. Gorelick (telephone: 415-323-8111 ext. 2141) or Manoutch Heidari, Kansas Geological Survey, Lawrence, Kansas (telephone: 913-864-5672).

The Orinoco and the Amazon: Hydrology, Sedimentology, Geochemistry, and Ecology of Large Tropical Rivers

Significant proportions of the Orinoco and Amazon basins are likely to be modified drastically during the next several decades by human activities. Deforestation, hydroelectric and other water-resources developments, and pollution from pulpwood processing, mining, heavy industries, and refineries will change the nature of the river flows, the solid and dissolved materials they transport, and the biological communities they sustain.

Not much is known about these two rivers. A few long records of river stage exist, but stream-gauging programs were initiated less than 20 years ago, so streamflow records are short and very few data are available on the discharge of dissolved and solid materials. Systematic studies of organic transport, nutrient cycling, and biological activities of these rivers were undertaken only recently. These short records and the results of recent or ongoing studies constitute the only basis for determining the characteristics of these rivers under nearly undisturbed natural conditions and serve as baseline data against which to measure future changes.

This program is organized to focus attention on scientific studies presently underway on the Rio Orinoco and the Rio Amazonas. A one-half day session of invited papers will be followed by sessions of contributed papers sponsored jointly by the Hydrology and Ocean Sciences sections. Anyone conducting studies on these rivers or on the coastal regions influenced by their flows is invited to submit an abstract of the results of the research for consideration in the program. Abstracts, in standard AGU format, should be sent by August 15 to Carl F. Nordin, Jr., U.S. Geological Survey, Box 25046, MS 413, Denver Federal Center, Lakewood, CO 80225 (telephone: commercial, 303-234-2320; FTS, 234-2320). In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Transport Processes of Excessive Sediment Loads

Much sediment transport theory is based on low and moderate sediment concentrations and may not be applicable for excessing sediment loads. The Erosion and Sedimentation Committee of AGU is sponsoring a symposium to review the state of the art for excessive sediment loads.

Some of the subjects already accepted for presentation include a comparison between research on hyper-concentrate sediment loads in the People's Republic of China and the United States, excessive sediment loads during the Mount St. Helens episode, pipeline transport of slurries, and an overview of the American Society of Civil Engineers Task Force on the effects of high sediment concentrations on velocity profiles and transport.

Submission of additional papers dealing with the general area of transport processes of excessive sediment loads is encouraged. Abstracts, in standard AGU format, should be sent by August 15 to Walter F. Megahan, Forestry Sciences Laboratory, 316 East Myrtle Street, Boise, ID 83702 (telephone: commercial, 208-334-1457; FTS, 554-1457). In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Papers presented at this session may also be published in *Water Resources Research*. Speakers who would like to have their papers considered for publication should provide a completed manuscript to Walter F. Megahan at the time of the meeting.

Treatment of Evapotranspiration, Soil Moisture Evolution, and Aquifer Recharge in Watershed Models

The session's invited and contributed papers will explore the manner in which the hydrologic phenomena of evapotranspiration, soil moisture evolution (including interflow), aquifer recharge, and aquifer return flows are treated in current (small) watershed and/or river basin models. Papers addressing the physical or conceptual basis for the treatment of the hydrologic components, the detailed structure of the mathematical models, the validity of the approaches taken, the case of calibration of the subsurface parameters, the experience in use of the models, etc., are welcome. Abstracts, in standard AGU format, should be sent by July 29 to H. J. Morel-Seytoux, Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523 (telephone: 303-491-5448 or 303-491-8549). In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Water Quality Analysis of Impoundments

A session will be devoted to the analysis of water quality in impoundments and river-run lakes. Among the topics of interest will be (1) mathematical modeling of reservoir water quality, including eutrophication, bacterial pollution, and toxic contamination; (2) the role of suspended solids in determining the water quality of impoundments and river-run lakes; (3) characterization of diffusion and dispersion in impoundments; and (4) the definition of eutrophication for reservoirs.

Other topics related to aspects of water quality peculiar to impoundments and river-run systems (in contrast to natural lakes) will also be considered.

Abstracts, in standard AGU format, should be sent by August 15 to Steven C. Chapra, Environmental Engineering Division, Civil Engineering Department, Texas A&M University, College Station, TX 77843. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

SPR: Interplanetary Physics (SS)
AMPTE Theory and Predictions

The Solar and Interplanetary Physics and the Magnetospheric Physics sections are cosponsoring this all-day special session. The purpose of the session is to increase awareness of the AMPTE science objectives and to expand the base of relevant theoretical work in anticipation of the launch of the Active Magnetospheric Particle Tracer Explorers mission in August 1984. (For more information on this mission, see Krimigis et al., *Eos*, p. 843, November 9, 1982.) Invited speakers will discuss the interaction of large plasma releases with the solar wind and the transport of ions through the magnetosheath, the magnetopause, and within the magnetosphere. Contributed papers are solicited, particularly in the areas of ion transport through the bow shock, magnetopause entry, magnetospheric transport, and wave excitation in mixed hot-cold plasmas. Papers presented at this session may also be published in the *Journal of Geophysical Research*. For additional information, please contact S. M. Krimigis (telephone: 301-953-7100). Abstracts should be directed to the SPR:SC/SS section and should clearly indicate that they are for this session. Please send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Tectonophysics (T)
Tectonics and Sedimentation in Active Continental Margins (jointly sponsored by Ocean Sciences)

This special session, jointly sponsored by the Ocean Sciences and Tectonophysics sections, will focus on new work dealing with the role of sedimentation processes in response to tectonics in active margins. Correlation of depositional systems to tectonics, diagenetic changes in response to tectonic processes, sediment stability in active margins and their causes, sediment deformation during deposition, and regional patterns of sedimentation are some of the topics to be included in this session. Abstracts, in standard AGU format, should be sent by September 14 to George deV. Klein, University of Illinois at Urbana-Champaign, 245 Natural History Building, 1301 W. Green Street, Urbana, IL 61801-2999. In addition, send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009. For more information, contact George deV. Klein (telephone: 217-333-2076).

Meetings cont. on p. 434

Sample Abstract

11.8cm

<u>Technique for the Preparation of Abstracts</u>

F. R. S. T. AUTHOR (School of Oceanography,
Hydro University, Watertown, Mass. 02172)
<u>S. C. N. D. AUTHOR</u> (USGS, Woods Hole, Mass. 02543)
(Sponsor: I. C. Alvin)

Follow this example in typing the abstract. The printing plates will be prepared by photographing the abstracts <u>exactly</u> as they are received, except that abstracts exceeding the maximum length (18 cm) or width (11.8 cm) will be cut to conform.

Use a good typewriter with a ribbon in good condition. A carbon ribbon gives the best results. Please use type of about this size. Use 12 pitch. There will be a reduction of 50% for the printed abstract volume.

18 cm

Follow these guidelines:
(1) Type title in capital and lower case letters except where all capitals are standard. Underscore entire title.
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Meetings (cont. from p. 433)

Volcanology, Geochemistry, and Petrology (V)
Calderas and Associated Volcanic Rocks (Krakatau Centennial)

The origin of calderas and their relation to pyroclastic volcanism was first brought into focus by the catastrophic eruption of Krakatau in 1883. One hundred years later, much work is concentrating on the history of caldera-forming volcanic sequences, caldera-collapse mechanisms, the internal structure of calderas, and petrologic evolution of caldera-related igneous rocks. These and other topics of volcanic calderas will be the subject of a centennial symposium at the AGU Fall Meeting; contributions are welcome. Please send the original and two copies of the abstract to Fall Meeting, 2000 Florida Avenue, N.W., Washington, DC 20009. For further information, contact the conveners: Stephen Self, Department of Geology, University of Texas, Arlington, TX 76019 (telephone: 817-273-2987); Grant Heiken, Geosciences Division, Los Alamos Scientific Laboratory, Los Alamos, NM 87545 (telephone: 505-667-8477); or Peter Lipman, U.S. Geological Survey, Box 25046, MS 913, Denver, CO 80225 (telephone: 303-234-2901).

Cascade Volcanism and Implications for Geothermal Resources

The Cascade volcanic arc in the northwestern United States has been the target of intense multidisciplinary geologic and geophysical study in recent years, with major focus on geothermal-resource potential and volcanic-hazard analysis. This special session will provide both broad summary overviews of recent work and also report on new detailed studies. Conveners are Patrick Muffler, MS 90C, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025 (telephone: 415-323-8111, ext. 4151), and Wendell Duffield, U.S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ 86001 (telephone: 602-765-7295). Send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Ocean-Ridge Basaltic Volcanism (Laki Bicentennial)

The eruption of Laki volcano in Iceland in 1783 is the most voluminous basaltic eruption of the historic record—25 km³. This special session, 200 years later, will focus on petrologic and structural features of ocean-ridge volcanism, both in Iceland and worldwide. Especially timely would be to compare the subaerial and submarine morphologic features of rift-zone volcanism. For further information, contact Haraldur Sigurdsson, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882 (telephone: 401-792-6596). Send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Structure and Dynamics of Hawaiian Volcanoes

Recent geologic, geophysical, and petrologic studies of Hawaiian volcanism, with special emphasis on the 1983 eruption of Kilauea. For information, contact Robert Decker, U.S. Geological Survey, Hawaiian Volcano Observatory, HI 96718 (telephone: 808-967-7328). Send the original and two copies of the abstract to Fall Meeting, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.

Meeting Reports

Valles Caldera Workshop

A Continental Scientific Drilling Project (CSDP) Workshop, attended by 87 scientists, focusing on the Valles caldera was hosted by the Department of Energy and the Los Alamos National Laboratory, on October 5–7, 1982, in Los Alamos, New Mexico. The caldera, a large, Quaternary magmahydrothermal system, lies at the intersection of the Rio Grande rift and the Jemez lineament in north-central New Mexico and is a prime site for the first deep drill holes.

One major objective of CSDP is to develop a broad scientific understanding of the roots of an active hydrothermal system associated with recent igneous intrusion. Surface geological, geophysical, geochemical, and hydrological data, along with information from shallow exploratory drillholes, will be used in the process of interactive development and testing of models and hypotheses for such systems. Ultimately, deep drilling will be essential to provide direct sampling of fluids and rocks at depth and to measure directly the critical in situ physical parameters. Thus, deep drilling research becomes an integral and necessary component in the synthesis, refinement, and verification of three-dimensional models of hydrothermal-magma systems and processes.

The Valles caldera was selected as an attractive site for deep drilling because (1) the regional and local geology, geophysics, and geochemistry have been well studied; (2) lithologic, geochemical, and thermal data have been obtained from many geothermal holes drilled to depths as great as 4.5 km; (3) liquid and possible vapor-dominated hydrothermal systems occur; and (4) geophysical anomalies suggest magma or interstitial melt at depth.

Key recommendations from this workshop include (1) the need for drilling several intermediate-depth holes (1000 m) prior to drilling a deep hole to enhance knowledge of the thermal regime at Valles, (2) the need for continuous coring in any CSD holes, and (3) the requirement to determine unequivocally whether magma exists beneath the caldera. The recommendations and the rationale for them follow.

Geophysics Working Group

Participants in the Geophysics Working Group of the Valles Caldera Workshop considered two related questions:

1. What is the evidence for interstitial melt under the Valles caldera?
2. What critical experiments should be performed to determine the presence of melt under the caldera?

The discussion group felt that presently there is insufficient evidence to say unequivocally that there is interstitial melt under the caldera. However, evidence in hand supports the thesis that a melt zone might exist at relatively shallow depth (<12 km) beneath the surface.

Preliminary geophysical evidence in support of melt is extensive:

1. Seismic analysis based on chemical explosions detonated near Farmington, N.M., shows both S wave and amplitude attenuation as well as P wave delays and teleseismic frequency changes suggesting anomalies beneath the caldera.
2. The lack of earthquakes under the caldera in comparison with an otherwise higher regional seismicity is evidence for a change in material behavior in the rocks below the caldera.
3. An upper crustal seismic transmission anomaly exists under the resurgent dome in the caldera.
4. Gerhard Suhr's midcrustal seismic analysis suggests an anomaly.
5. An electrical conductor exists at 10–12 km below the caldera and is coupled with a regional electrical anomaly.
6. The caldera rests on an area of very high heat flow.
7. The temperature gradient analyses of Swanberg suggest a magmatic heat source.
8. The gravity analyses of Cordell, Segar, and Wilt suggest an anomaly.
9. The very high temperatures (320°C) at the base of the HDR Fenton Hill holes and the direction of the measured gradients suggest a major heat source. Perhaps the most compelling evidence concerns the recentness and long history of volcanism, together with geological arguments, and thermal modeling.

The Working Group felt that future geophysical work should concentrate first on completion of the reconnaissance investigations current, then initiate high resolution geophysical research concentrating on the upper 10 km of the crust. This high resolution phase of research should focus on six topics.

Recommendations

1. Intermediate-depth drilling. Several intermediate-depth holes should be drilled in and around Valles caldera to obtain additional thermal gradient measurements to be used for understanding the thermal regime in thermal modeling. Cores should be obtained from the holes to aid in refining the geology. Holes should be logged to obtain other physical properties useful in modeling (e.g., density measurements).
2. Thermal modeling. Additional detailed thermal modeling using all available geologic and geophysical constraints is needed. Modeling should endeavor to determine the vertical extent of the upper hydrothermal convective system and model the deep crustal thermal regime.
3. Seismic research. Additional seismic studies should be designed to focus on the three-dimensional structure of the upper 10 km of the crust near the caldera.
4. Electromagnetic research. High spatial resolution electromagnetic studies are needed to delineate the crustal conductive anomalies in an effort to map the known near-surface hydrothermal system and the suspected deeper regions of melt.
5. Gravity modeling. Detailed gravity modeling using all available geologic and geophysical constraints is necessary to strip the effects of the Phanerozoic cover and facilitate modeling of the deep crustal structure beneath the caldera. Such modeling may yield additional bounds on the suspected silicic magma body.
6. Downhole geophysical sensors. A variety of downhole geophysical high temperature sensors should be developed to be used in available holes, and results should be coupled to surface geophysical surveys.

Geochemistry Working Group

The question addressed by the Geochemistry Working Group was, What is the nature of the hydrothermal systems created when a silicic magma body is emplaced beneath the Valles caldera? To answer this question, data must be collected that define the hydrothermal systems with respect to fluid chemistry, geometry, and solid phase composition. Stated another way, What processes produce the various systems associated with the Valles caldera?

To pursue these data, we recommend drilling five exploratory holes 1000 m deep (see Figure 1) to learn more about the nature of these hydrothermal systems: their recharge, discharge, permeability, and associated phase chemistry. Specifically, we want to learn more about the following points (numbers refer to the numbers in Figure 1).

Recommendations

1. The thermal regime in the southwest ring-fracture zone to determine if it is a discharge zone and to discover more about differences in fluids and alteration phase assemblages in ignimbrite, carbonate, and the Precambrian rocks. This hole could be located near the youngest moat rhyolites in the caldera and thus satisfy one objective of the Geology Working Group.
2. The intersection of the northeast fracture zone and the central graben faults to determine if this area is a recharge zone for the deep system.
3. The nature and degree of communication, including wall rock alteration, between the suspected vapor dominated zone and deeper hydrothermal systems in the Sulphur Springs area. Indications are that the boundary between these zones moved down with time.
4. The northeast extension of the hydrothermal system into the Jaramillo Creek area along the central graben faults.

Our objective for a deep hole is to study a complete sequence of metamorphic events: (1) dynamics of a vapor-dominated system and deeper hydrothermal system with associated recharge and upflow, (2) mineralization, and (3) depth to and position of the heat source. With the data available now, core location of hole 3 will lead to investigation of deeper metamorphic systems extending into the Precambrian and will define their connection structurally and chemically with the shallower hydrothermal systems. This objective supports the Drilling Technology Working Group recommendation to core continuously to the depth desired. Hole 3 presents a unique opportunity to study completely the mechanism of infiltration metamorphism (fluid composition and transport as well as alteration assemblages) and deeper more diffusionally controlled metasomatism and their ultimate relation to the deep heat source.

Geology Working Group

CSDP may provide the first sampling of an active pluton beneath a caldera complex. From the perspective of geology, these samples will add to the knowledge of magmatic and crustal evolution. The points describe the need for general and regional studies, values of deep sampling, need for complexes, and a choice for the deep-drilling locality within the Valles caldera.

Recommendations

1. We need a synthesis report on caldera systems and the regional geologic studies. Maximum scientific value of CSDP will occur only if results of drilling can be interpreted adequately. Interpretation requires knowledge of the regional geologic setting for deep drill holes and an adequate predictive model based on studies of comparable localities. For deep sampling of magma-hydrothermal systems in an active caldera complex, the predictive model must be based on other active calderas and on "fossil" caldera complexes exposed by erosion. There is an extensive literature on both active and fossil caldera-geothermal systems, but an adequate comprehensive summary of these systems is lacking. An important first goal for this phase of CSDP must be the preparation of such a summary. If the Valles caldera is a drilling target, its deeper features should be anticipated in terms of other "type" caldera systems. The summary document may serve as a basis for selecting the best CSDP location for study of an active hydrothermal system.

Earlier research on well-exposed fossil caldera systems is an important basis for extending the scientific value of CSDP and a strong argument for deep drilling in an active caldera system. Mineralization, alteration, and thermal aureole development are most active in the last stages of caldera magmatic history. Older exhumed caldera systems are recognized by these terminal events. Deep drilling at active caldera systems may clarify an igneous-hydrothermal history that might then be extrapolated to economically important calderas worldwide.

For the Valles caldera, the relevant geologic framework includes Precambrian rocks of the Nacimiento Uplift to the west, overlying Paleozoic sediments, and Cenozoic sedimentary and igneous rocks in the east that aid in understanding development of the Rio Grande rift with its associated deposits in basins east and southeast of the Jemez Mountains.

2. We need deep samples from an active caldera system. The expense and effort of deep drilling will be best repaid if drilling is designed to emphasize understanding of geology at depth. In Valles caldera, there is knowledge from drilling at Fenton Hill and other localities outside the western margin of the caldera and from drilling in the resurgent dome within the caldera. Depths of 4.4 km and temperatures of ~330°C were reached. Outflow tuffs, caldera fill, older Cenozoic volcanic rocks, Cenozoic and Paleozoic sediments, and Precambrian basement were sampled. Conventional drilling yields much information; the underlying pluton margin remains unknown. Features of the intrusive aureole are unknown.

Down-hole geophysical studies and stress-relaxation research can be made on oriented core. Detailed sampling must be a major goal of CSDP.

3. We must collect deep core samples. Collection of deep samples must be a major goal of CSDP. Currently available sampling technology should be used extensively early in the CSDP drilling schedule. Cored exploratory holes will answer many questions about intra-caldera lakebed and volcaniclastic stratigraphy, detailed magnetostratigraphy (the Valles caldera already provided the type locality for the brief Jaramillo event), and Cenozoic tectonism. Greater emphasis, however, must be on adequate deep sampling, where the greatest rewards lie. An overall geologic goal of CSDP must be collection of these unique, deep samples. Preliminary exploratory drillholes can be cored throughout, but the payback from deep holes will be best by drilling to depth as rapidly as possible and then concentrating on sample collection.

4. Siting of CSDP deep holes: A geologic perspective based on Valles caldera. The value of CSDP deep drilling is based on exploration of deep geologic features. Ability to reach deep magma-related features, in particular the pluton margin, must be the major emphasis. One criterion that might help to site a deep hole is occurrence of the youngest volcanic centers. The young moat-zone silicic domes of the Valles caldera are appealing targets for drilling localities. Besides drilling near the most recent eruptive pathways, a locality near one of these young domes will help to investigate deep features along the ring fracture that bounds caldera collapse. Such fracture systems can be seen in older, dissected calderas to be major pathways for hydrothermal alteration and mineralization. Drilling "inboard" of the ring fracture near one of the young silicic domes could provide a sample of active processes along this vital fracture system. The location of this hole could satisfy the drilling objectives of the Geochemistry Working Group. As a second priority, another deep hole "outboard" of the ring fracture system would provide samples from a nearby but relatively stable section of volcanic deposits and country rock. Drilling near one of the youngest silicic domes will be a favorable locality in the Valles caldera from its value for CSDP and also because of the existing data base for areas outside the western caldera rim (Fenton Hill) and in the resurgent dome (Union Oil's geothermal drilling program).

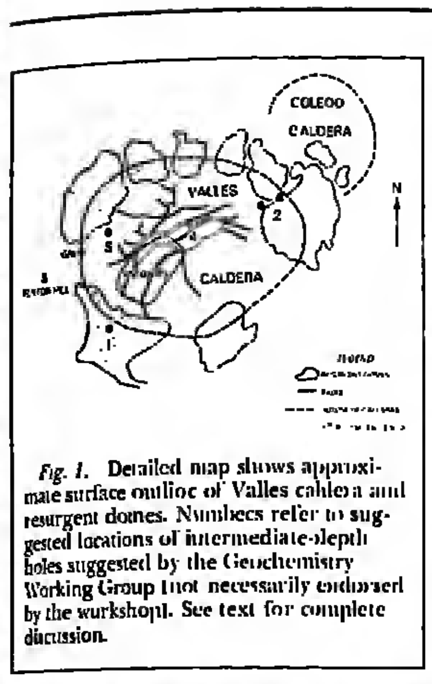

Fig. 1. Detailed map shows approximate surface outline of Valles caldera and resurgent domes. Numbers refer to suggested locations of intermediate-depth holes suggested by the Geochemistry Working Group (not necessarily endorsed by the workshop). See text for complete discussion.

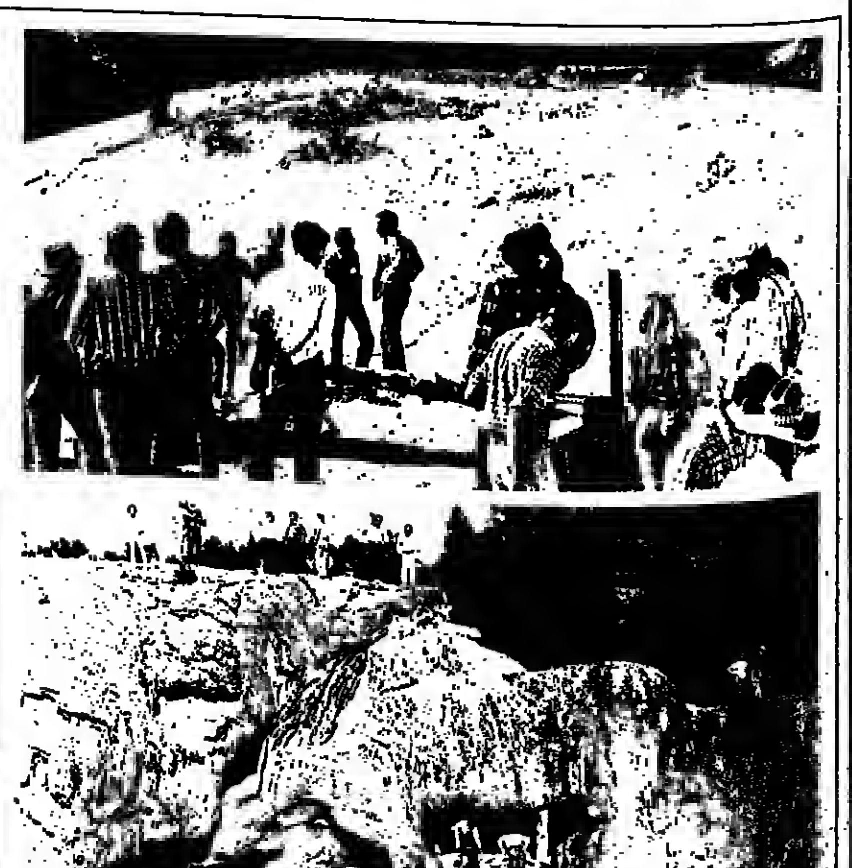

Fig. 2. (Left top) Exposed in downward succession in roadcut are two members of the Valles caldera, N.M., rhyolite: (1) vitrophyric blocks of the basal part of Banco Bonito Member glass flow and (2) well-bedded pumice and ash of El Cajete Member. Charcoal found at the base of the uppermost ash bed in the El Cajete section give an age of 42,000 years B.P.; the overlying Banco Bonito Member is about 0.05 Myr old. (Top right, bottom left) Participants of the Valles Caldera Workshop examine ruins of the Sulphur Springs resort in New Mexico, where tourists bathe in waters from hot springs and mud pots. A variety of thermal features occur: fumaroles, hot springs, mud pots, and gaseous cold springs. Temperatures in the springs range from ambient to boiling, pH may be less than 1, and SO_4 concentration may be as high as 8,000 mg/l. Data suggest that hot gases are in equilibrium at depth with a reservoir of about 200°C. (Bottom right) Soda Dam, near Jemez Springs, N.M. The travertine dam was deposited by thermal waters that discharge from a strand of the Jemez fault zone. Waters (there are at least 10 springs and seeps in this area) discharge at ~48°C, Cl = 1500 mg/l. The ratios of very soluble elements, such as Na, Li, Cl, and B are practically identical to those from the deep fluid within Valles caldera.

Drilling Technology Working Group

Existing drilling technology is adequate to drill boreholes in the Valles Caldera to temperatures of 300°C. This judgement was reached after reviewing experience gained in development of the Union Geothermal Baca site and the Los Alamos National Laboratory Fenton Hill HDR site. This experience covered all aspects of drilling in volcanic, sedimentary, and crystalline basement rocks and at substantial temperatures (~340°C) and depths (~4570 m). Continued drilling into deep basement following operations needed to study the shallower hydrothermal system would be both difficult and costly. We recommend drilling separate holes to investigate each of the two thermal regimes.

Drilling experience indicates strongly that cuttings are inadequate and that coring, either total or intermittent, is required. A coring bit developed for the HDR project may allow both reasonable drilling rates and ability to core continuously, especially in the sedimentary sections. Of particular interest is the symbiosis that could be developed between coring and downhole measurements. After core is taken and retrieved, the bit is pulled back some chosen distance, and a sequence of logging tools is run through recently cooled openhole region. This sequence allows great economy in use of the drill rig and an ongoing understanding of the region drilled. In addition, cooling allows use of conventional logging tools and techniques that could not run at in situ temperatures.

As in the JOIDES program, our primary goal is obtaining samples and measurements; drilling methods should be tailored to optimize this goal.

Recommendations

1. Drilling technology should facilitate sample (core) collection and borehole geophysical measurements.
2. The hydrothermal system located in volcanic and sedimentary strata should be examined and tested with a borehole terminating in the Precambrian granite (~3050 m depth).
3. This borehole should be continuously cored. Use of a recently developed hybrid roller cone/polycrystalline diamond cutter coring bit (R. Peridi et al., Evolution of a hybrid roller cone/PDC core bit, *Trans. Geothermal Res. Council, 4*, 1980) is recommended. Use of this method of drilling allows geophysical logging through the coring bit into the open hole without removing the drill string. Substantial cooling obtained by this technique allows use of conventional logging tools.
4. High temperature basement underlying the hydrothermal system should be examined and tested with a separate borehole.
5. Basement sampling should be done on an intermittent basis with full size cores by using the coring bit described. Geophysical logging should be done immediately after retrieval of the core. A method of continuous coring in which a small diameter core is cut by a roller cone bit that has a smaller diameter center hole and is then removed by reverse circulation should be examined ("coring spitting bit").
6. Further examination of methods for reducing maximum temperature seen by the drilling bit, the drilling string, and the measuring equipment is desirable. One possible method is use of an insulated drill string.
7. Certain measurements require that tools be at in situ temperature. Substantial technical development is required if temperatures exceed 300°C.
8. Further development work on high-temperature drilling fluids, corrosion inhibitors, and lost-circulation materials will aid deep drilling operations.
9. Examination should be given to high temperature turbodrill systems and to methods that adapt them to existing high-performance roller-cone bits. Such development will substantially reduce wear on the drill string.
10. Use of existing wellbores would aid technical developments. Wellbores exist at the Fenton Hill HDR site and at the Union Geothermal Baca site.

Acknowledgments

Plenary session chairmen were John Whetten and Grant Heiken. Fraser Goff and Stephen Bolivar were field trip leaders. Working group chairmen included Jamie Gardner, David Vaniman, Mark Ander, Robert Riecker, William Laughlin, Robert Charles, Fraser Goff, John Rowley, and Robert Potter. The workshop was sponsored by the Office of Basic Energy Sciences of the U.S. Department of Energy.

This meeting report was prepared by Robert E. Riecker of Los Alamos Scientific Laboratory, Los Alamos, NM 87545.

HDR Geothermal Exploration

Introduction

Hot dry rock (HDR) is defined as that part of a geothermal anomaly where the fluids needed for production of steam or hot water are lacking. Most of the world's geothermal resource is not present in the form of natural hydrothermal systems but as HDR. Development of this resource through the use of manmade geothermal systems is in progress in several countries. The largest of these experiments, the Fenton Hill HDR geothermal project, is funded by the U.S. Department of Energy and the governments of West Germany and Japan. This project is located a short distance west of the rim of the Valles Caldera in the Jemez Mountains of New Mexico. As the Fenton Hill experiments progressed, it became evident that the location and extent of the HDR geothermal resource in other areas should be evaluated and that potential HDR drilling sites be located as part of a comprehensive program needed to encourage its development. Because the HDR resource lacks the sharp physical and chemical contrasts produced by natural fluids, it presents different exploration problems from those of conventional hydrothermal exploration. The purpose of a workshop, held in Los Alamos, New Mexico, June 21–23, 1982, was to review geological, geochemical, and geophysical exploration methods currently used for HDR recognition and resource evaluation and to evaluate new ideas for HDR exploration.

Heat Flow Criteria

Heat flow, because it involves direct temperature measurements, is usually the ultimate standard for evaluating geothermal potential. Its importance increases as the scale of resolution narrows to that of choosing drilling sites.

Crustal heat flux varies between regions of relative geological stability such as eastern or midwestern North America and the more active regions like western North America where crustal temperatures are usually hotter.

For stable regions J. Costain (Virginia Polytechnic Institute and State University) cited several geological settings that seemed promising for HDR. These take advantage of the fact that heat flow is the product of thermal gradient and thermal conductivity; therefore, regions of low thermal conductivity can have rather high thermal gradients and hence high temperatures at moderate depths, even though heat flow is only average. Heat flow is further enhanced if local crustal heat generation is high. Hence, two interesting HDR possibilities would be regions of normal gradient but deep, relatively insulating sedimentary cock and regions of high heat generation, such as a granitic pluton overlain by "blanketing" sedimentary layers.

W. Hinze (Purdue University) elaborated upon some variations where crustal heat is concentrated by a local good thermal conductor such as a salt dome, by hydrothermal circulation, by residual magmatic heat, or by upper mantle sources where the thermal effects have not yet diffused to the upper crust. Hinze cited thermal anomalies within the Mississippi Embayment as a possible example of "channeling" by a good thermal conductor. K. German (University of Nebraska at Lincoln) attributed high temperatures in western Nebraska to the hydrothermal circulation mechanism, as did D. Hodge (SUNY, Buffalo), to explain high bottom hole temperatures in basement rock near Auburn, New York.

Hence, from the standpoint of heat flow methods HDR exploration in older "stable" continental crust involves three criteria: (1) locating regions of relatively high heat flow, (2) identifying regions of low thermal conductivity, and (3) determining radiogenic heat production in basement rock.

Because of a far greater density of thermal anomalies, tectonic zones such as the western United States have enjoyed a much higher level of geothermal exploration, and many geothermal areas have been identified. Thus, an obvious HDR exploration technique cited by D. Blackwell (Southern Methodist University) and M. Smith (Los Alamos National Laboratory) is to obtain heat flow data in the "conductive haloes" surrounding known hydrothermal sites. Indeed, these areas often have sufficient numbers of "dry holes" to make them more interesting as HDR sites than as conventional sites. Steep geothermal gradients are, of course, direct indicators of high temperatures at accessible depths, but Blackwell indicated the need for a more reliable and easily interpreted way of using heat flow to project thermal effects to great depth. Groundwater and hydrothermal water circulation add further complications, including extremely high apparent surface heat flow, but there is a growing body of experience in modeling these situations.

Further Work in Heat Flow Methods

The outlines for adequate heat flow criteria in HDR exploration are given above. However, the panel noted that these criteria could be improved and systematized by some additional efforts.

1. A higher density of heat flow determinations would be extremely useful; it is particularly important to extend measurements beyond the immediate area of a wet geothermal or HDR site in order to reduce ambiguity in interpretation of heat flow data and to model convective heat transfer better.
2. Better communication between the academic community and the geothermal industry would be beneficial in obtaining basement temperatures and cores for measurement of basement temperature, thermal conductivity, and heat generation.
3. The Decade of North American Geology (DNAG) series of maps could serve as the outlet for four additional maps: (1) temperature at top of basement, (2) basement heat production, (3) heat flow at basement surface, and (4) surface heat flow.

Seismic Criteria

If one were to look only at the relatively small effects, due purely to temperature, on seismic velocities, then only subtle variations in seismological observations would be observed. The utility of seismic methods is in determining crustal structure and thermally associated but often indirect phenomena such as the presence of fluids.

Many of the seismic methods are so well established that they are almost taken for granted. W. Laughlin (Los Alamos National Laboratory) described reflection surveys that were used to characterize depth to basement at the first HDR site at Fenton Hill, New Mexico. Magma bodies are potential HDR thermal sources, and S. Kaufman (Cornell University) showed how reflection profiles helped define a magma layer intruded beneath the vicinity of Socorro, New Mexico. L. Braile (Purdue University) mentioned the strong structural controls provided by seismic refraction in the Yellowstone-Snake River Plain region; these included substantial velocity decreases, as much as 30%, attributed to fluids. Although the fluids would not themselves be the object of HDR exploration, they could contribute to heating nearby rock in the "conductive halo."

Seismic methods are particularly well suited to locating disturbed zones that have been heated hydrothermally or by magma. K. Aki (Massachusetts Institute of Technology) noted that almost all the hot zones currently established as geothermal sites are characterized by deep crustal low-velocity cores. These comprise not only giant systems such as Yellowstone, but also the Jemez Caldera (although velocity surveys inside and outside the caldera did not play a role in originally choosing this HDR geothermal site). Three-dimensional teleseismic P wave delay studies have strikingly outlined several low-velocity cores that represent hot rock that provides heat both to the local hydrothermal systems and to the halo of hot but dry rock. Seismicity serves to delineate possible HDR reservoirs in a number of ways: It can locate possible intrusions such as the Socorro magma layer; on the local scale it can provide information on stress directions as a guide to drilling. Contrary to the case for conventional reservoirs, seismicity is a negative indicator for manmade systems because of the danger of induced earthquakes and of water loss through active faults.

Further Work in Seismic Methods

Future work in seismic HDR exploration should take advantage of those properties that are most sensitive to crack structure and pore fluids as ways to define the general form of geothermal structures: (1) teleseismic S wave structure to define three-dimensional (3-D) structure as done for P waves, (2) determination of S velocities, Poisson's ratios, and Q^{-1} in refraction surveys, (3) controlled surface wave studies to improve resolution of V, and Q^{-1}, (4) detailed studies of known conventional hydrothermal and HDR areas to gain experience in seismically defining these reservoirs.

Magnetotelluric Criteria

Electromagnetic methods, magnetotellurics (MT) in particular, are extremely useful in geothermal exploration because of the sensitivity of rock conductivity to water content and to elevated temperatures. MT can target HDR resources in two important ways. As a regional exploration method, MT can be used to map the crustal deep electrical conductor. M. Ander (Los Alamos National Laboratory) showed five long two-dimensional models developed from approximately 200 MT soundings in Arizona and New Mexico. These models indicate strong evidence for a correlation between the depth to deep electrical conductor and surface heat flow as well as with regional tectonics.

One of these models, from Seligman to Yuma, Arizona, was used in a presentation by E. Aiken (University of Texas) and M. R. Hong (University of Texas) to indicate a correlation between the depth to the deep crustal conductor and the depth-to-Curie point. M. Ander and T. Shankland (Los Alamos National Laboratory) showed results of a correlation study of worldwide MT field data and crustal temperature obtained from surface heat flow. A pronounced result of their study was that even the most resistive crustal regions have conductivities several orders of magnitude better than laboratory samples and that this is easily explained by the presence of volatiles, water in particular. Most importantly, the data could be well represented by a straight line fit on a log versus 1/T plot indicating an excellent correlation between crustal electrical conductivity and crustal temperature. G. R. Jiracek (San Diego State University) suggested that the deep crustal electrical conductive horizon may occur where an impermeable, ductile cap traps pore fluids beneath. Ductile flow mechanisms are thermally activated processes that involve charge defects, lattice dislocations, or atomic diffusion, all of which enhance solid state electrical conduction. If active magma injection destroyed the integrity of the ductile cap, trapped fluids would escape, resulting in an overall decrease in conductivity. The final electrical signature would depend on thermal gradient, relative impermeability of the cap, extent of the pore fluids beneath, and amount of magma intrusion. Because temperature would likely be the major variable in a given geologic province, Jiracek also felt that the depth of a conductive layer, even if caused by a ductile layer, would provide a measure of the thermal gradient. Therefore, it is likely that estimates of crustal temperature and regional heat flow can be obtained from estimates of the depth to crustal electrical conductor.

As a local exploration method, MT can be used to map the structure of resistivity changes at a potential HDR site. This requires high quality MT data and a tight MT station spacing. For both the regional and the site specific exploration, problems exist in modeling and in interpreting the field results. A. Orange (Emerald Exploration, Inc.), S. Park (MIT), and D. Chambers (Woodward-Clyde Consultants, Inc.) discussed the nature of some of the pitfalls of MT interpretation in both two and three dimensions. MT interpretation is a complex art, even in many cases where the data appear straightforward; recognition of this complexity is a major step toward the realization of the method's full capabilities. Intense study of a wide variety of two- and three-dimensional models will provide the interpreter with valuable, critical insight. MT surveys should be planned by using this insight.

Further Work in Electromagnetic Surveys

The electromagnetics working group had several specific recommendations for further work.

1. In the past decade, well over 5000 MT soundings have been completed in the United States. These represent an extraordinarily valuable data base for determining the depth to the deep electrical conductor. It was suggested that these data be compiled in a single data base and analyzed. An international project to do this has been endorsed already by the National Academy of Sciences. This would be of value in further confirming the correlations between electrical conductivity, heat flow, depth-to-Curie point, and regional tectonics.

2. A continuous exploration program, using electrical methods, should be directed toward locating conductivity anomalies in the United States. These could be either hydrothermal or HDR systems. The distribution of heat flow and electrical properties may well be useful in differentiating the two types of systems.

3. A major uncertainty exists in knowing how to interpret enhanced electrical conductivities in the crust. Possible mechanisms are numerous. Although we have some measure of understanding of these effects, there is insufficient information to judge how these effects persist over time. For instance, can pure fluids persist in enhancing conductivity over geologic time at temperatures of several hundred degrees or do they form hydrated minerals and hence change rock conductivity? In addition, long-term measurements of electrical conductivities in rocks need to be undertaken at geologic temperatures and pressures to understand changes with time.

Gravity and Magnetic Criteria

There are many ways in which gravity and magnetic methods can be applied to exploration for HDR resources. Gravity analysis is well suited for mapping depth to rocks with low permeability. Magnetic methods are not usually as well suited for this because magnetic "basement" seldom coincides with geologic "basement." Gravity can be used to some minor extent in studying the nature of the sedimentary blanket. Both gravity and magnetic surveys are important methods for delineating both regional and local structure in the Phanerozoic and the basement. They are particularly good for locating faults, suture zones, and old rift structures. Magnetic surveys may be used to determine depths to the Curie isotherm. A shallowing in the depth to the Curie isotherm may suggest a thermal upwelling and therefore a possible HDR target area.

J. Costain, L. Glover (Virginia Tech), D. Hodge, and K. Fromm (SUNY, Buffalo) described the use of gravity data in targeting HDR sites in the eastern United States, while W. Hinze, L. Braile, R. von Frese (Purdue University), G. R. Keller, R. Roy (University of Texas at El Paso), and P. Morgan (Lunar and Planetary Institute) described gravity applications in the midcontinent United States. In these studies, gravity and magnetic data covering broad regions have been observed, compiled, and in some cases filtered to enhance particular attributes of the anomaly field. These maps are proving useful reconnaissance tools in mapping tectonic/lithologic regimes that serve as guides to localize more detailed geophysical and geologic studies.

In particular, gravity and magnetic surveys have helped in investigations of silicic and alkalic intrusive bodies, which are potential radiogenic heat sources. Silicic intrusives are commonly characterized by gravity minima of the order of a few tens of milligals and negative magnetic anomalies. However, some plutons studied in the midcontinent are associated with relatively high magnetite contents resulting in strong localized magnetic anomalies. The gravity signature of these high-magnetite plutons is absent or slightly positive. By contrast, alkalic intrusives are generally marked by both intense positive gravity and magnetic anomalies.

In two separate papers, I. Won (North Carolina State University), C. Aiken, and B. Hong discussed the inversion of magnetic data to determine the depth to Curie point isotherm. Aiken and Hong described how depth to Curie point estimates they made along a profile from Yuma to Seligman, Arizona, correlated with estimates of depth to deep crustal electrical conductor made along the same profile by M. Ander using MT data.

Further Work on Gravity and Magnetic Methods

The gravity and magnetic working group identified several areas for further work in applying gravity and magnetic methods to HDR exploration.

1. More case studies are needed.

2. Petrophysical studies are needed to obtain precise measurements of density and magnetization of rocks of interest. Studies addressing the magnetization of rocks as a function of temperature for extended times are considered especially important.

3. Gridded filtered data sets must be generally available.

4. Although magnetic maps are widely available, digital magnetic data are not. It would be useful to make such data available.

5. It would be profitable to further study the correlation between the depth-to-Curie isotherm estimates and surface heat flow and the depth to the deep crustal electrical conductor.

Geologic Methods

Geologists attending the workshop all emphasized a multidisciplinary approach to HDR exploration. Their role is to provide the geological framework for geophysical data in regional HDR surveys and to characterize the genesis and thermal history of heat sources within geothermal areas associated with recent volcanism or older silicic plutons. The geologist's role has changed little since the Hot Dry Rock Resource Evaluation Panel (HDRAP) of the Energy Research and Development Administration defined the variety of geological surveys needed for HDR exploration and development.

Within igneous systems, which make up most of the known geothermal resource areas (KGRA's) of the United States, the geologist's role in defining the HDR resource is substantial. To understand the extent and magnitude of hydrothermal and HDR components of an igneous system requires detailed information on the structural setting, ages, distribution, volume, and composition of volcanic units, the hydrologic setting, and chemistry of rock-water interactions within the system. The rate of fracture formation and fracture healing within these systems must be determined. All this resource definition requires drilling and careful analysis of cores, cuttings, and geophysical well logs.

Some of the most useful data sets for the geologist are those from the many wells drilled for hydrothermal development that have high temperatures but no production of fluids. By keeping records of "hot but dry" wells within KGRA's, the high-grade HDR resource may be best evaluated.

Examination of regional thermal anomalies is mostly in the realm of geophysical surveys. However, the characterization of HDR reservoir rocks depends upon good physical and petrologic studies.

E. Padovani (National Science Foundation) discussed the utility of petrology of xenoliths from young volcanic rocks as a tool for geothermal evaluation. It is possible to use mineralogic geobarometers and geothermometers to calculate thermal gradients; these serve well as supplements to measured heat flow.

A major problem in HDR resource evaluation is determination of changes in the stress regime and permeability with depth in a variety of geologic settings. These data are needed for identification of rock units to serve as HDR reservoir rocks.

Compilation and evaluation of existing geological and geophysical data would be easier if there were a clearinghouse for published and proprietary information. Also needed are better curatorial facilities for the preservation of drill cores and cuttings; perhaps such facilities could be established through a continental scientific drilling program.

Case Studies

W. Laughlin and M. Smith described the process of selecting the first hot dry rock geothermal site in the Jemez Mountains, New Mexico. Of primary importance to site selection was the published data available on the extent, age, and nature of the Valles Caldera. Heat flow measurements along the western edge of the caldera, structural mapping, and a slim exploratory drill hole to the Precambrian "basement" were key factors in site selection. Determination of the degree of faulting and jointing within the plutonic-metamorphic reservoir rocks was not possible and could be determined only by drilling. Drilling slim exploratory holes, with numerous cores, provides many of the answers and appears to be the best local site evaluation technique; it certainly was at the New Mexico site.

Hodge and Fromm used heat flow, temperature gradients, and gravity surveys to search for hidden thermal anomalies in the northern Appalachian basin. Initial results indicate that variations in temperature gradients are due to heat generation in granitic plutons in the basement (similar to the anomalies described by J. Costain in the Atlantic coastal plain). Recent drilling in western New York state has indicated that not all thermal anomalies are related to buried granitic plutons; some appear to be the result of hydrothermal circulation along faults and fractures within the basin.

Heat flow measurements, bottom-hole temperatures in oil and gas wells, and residual Bouguer gravity maps were the basis of a geothermal resource assessment of Nebraska by Gosnold and German (University of Nebraska). Two areas within the state have high heat flow. Within the panhandle of Nebraska the anomalies appear to be due to updip flow of deep aquifers from the Denver-Julesburg basin. High heat flow within north-central Nebraska is more difficult to explain; it may be related to water flow along fractures in the Dakota group or to buried granitic plutons. More drilling into Precambrian basement rocks is needed to evaluate the HDR geothermal resource of Nebraska, but its potential seems high.

Geothermal exploration strategies used in the Rhine Graben by the European Communities were presented by B. Hollers (Los Alamos National Laboratory and Gerver... Walter). These include (1) work on the gneisses and schists of Hercynian age, granites of Carboniferous age, and Paleozoic sedimentary rocks; (2) bottom-hole temperature and heat flow measurements; (3) Bouguer gravity anomalies; and (4) tectonic analysis. Diapiric rise of mantle under the Rhine Graben and higher temperature gradients were identified through the use of, in addition to those surveys described above, refraction and reflection seismic profiles, MT surveys, aeromagnetic surveys, and electrical surveys.

This meeting report was contributed by G. H. Heiken, M. E. Ander, and T. J. Shankland, Los Alamos National Laboratory, Los Alamos, NM 87545.

30th Pacific Northwest Regional Meeting

September 30–October 1, 1983

Western Washington University
Bellingham, Washington

Convenors: Myrl E. Beck, Jr. and David C. Engebretson

CALL FOR PAPERS

Abstract Deadline:
August 1, 1983

Special symposia will be held on Evolution of oceanic plates in the eastern Pacific; volcanism and seismotectonics of the Cascade Range; evolution and character of the crystalline North Cascade Range of Washington and British Columbia; Tertiary tectonics of the western Washington and Oregon Coast Range province, with special attention to the origin of sedimentary basins.

For information on program contact

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For registration information or to mail abstracts, contact

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Call previously published in EOS, May 17.

AGU

1983 AGU Fellows

Peter L. Bender—For his innovative work in the development and exploitation of new advanced systems for generation of precise data for a variety of geophysical applications: variations in the earth's rotational rate; lunar orbit and lunar mass distributions; tectonic plate motion; crustal movements in seismic zones; global gravity field; and precise geometric positioning.

Lynn W. Gelhar—For his contributions to the science of groundwater hydrology and particularly for his application of stochastic methods to that field.

Hugh H. Kieffer—For his contributions to the investigation of planets through infrared techniques.

Jacob Rubin—For his outstanding career in science during which he has made significant contributions in soil science and in the theory of solute transport by groundwater.

Marx Brook—For extensive and original contributions to physics that have resulted in increased understanding of electrification and severe storm dynamics and their effect in the atmospheric processes.

G. V. Gibbs—For greatly expanding our knowledge of crystal structures and crystal chemical characteristics of many and diverse groups of minerals.

Michael W. McElhinny—For outstanding contributions in paleomagnetism and plate tectonics.

Edward C. Stone—For the continued excellence of his research in cosmic ray physics and for his extraordinary efforts on behalf of his fellow scientists as Voyager Project Scientist.

Harmon Craig—For sustained and diverse contributions of the most fundamental nature to the field of geochemistry.

Dennis E. Hayes—For outstanding contributions in marine geophysics—exploration concepts, and syntheses.

John G. Ramsay—For revitalizing structural geology by careful quantitative studies of seemingly minor features, showing how much can be read from them.

James R. Wallis—For research and leadership in the application of statistics and stochastic processes in hydrology.

Herbert S. Bridge—For continued contributions of the highest scientific quality to our understanding of the solar wind and its interaction with the planets of the solar system.

Andrew P. Ingersoll—For his contributions to the understanding of planetary atmospheres through the interpretation of spacecraft data.

Frank M. Richter—For providing a better understanding of convective processes in the earth's mantle.

Membership Applications Received

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation; the letter A denotes the Atmospheric Sciences section, which was formerly the Meteorology section.

Regular Member

Kathleen W. Baird (V), Vira Chankong (H), Claire B. Davidson (H), Peter M. Demicco (H), Stephen J. Derksen (T), David A. Gell (SA), John D. Horel (A), Gary R. Huber (T), Jess B. Kozman (T), Eve Kuniansky (H), Russell W. LaForce (H), H. Richard Naslund (V), James K. Nicholls (O), Michael Rowen (V), Steven D. Scott (V), Ping Sheng (S), Joseph W. Troester (H), Roger A. Wait (S), James E. Wolfe (S).

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Ruben A. Aparicio (O), Clay Bogusky (O), Carolyn Brown , Stuart Davis (S), Steven Fleisher (G), Mark J. Gresko (S), Zaki Y. Harari (T), Daniel Hillman (T), Masahiro Hoshino (SM), Kenneth W. Hudnut (V), Nikolaus K. Klever , Robert J. Langridge (V), William W. Leslie (S), John L. Lurick (O), Laura L. Lundberg (A), Nan MacGregor-Scott (S), Keith I. Mahon (V), Kyoung W. Min (SM), Eugene L. Murray (H), Isabelle Muszynski (A), Dean Ramlall (H), Heather S. Saunders (S), Sherilyn Talada (T), James G. Tsolinas (V), Mel Wagstaff (S).

Associate Member

Paul Backlawski (T), Duane C. Bues (H), Mark Dowding (GP), Kenneth R. Hahn (V), Henry Jurenka (A), George Marlian (SM), John Murphy (H), Fred Charles Rathbun (H), Roderick E. Trice (T), Philip G. Wendt (O).

Nominations for 1984 AGU Fellows

Nominations for Fellowship in the Union are being sought by the Fellows Committee and the Section Selection Committees. Nominees for Fellowship should be scientists who have attained acknowledged eminence in a branch of geophysics. The total number of Fellows elected each year cannot exceed 0.1% of the total membership.

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Send nominations for forwarding to the appropriate Section Selection Committee to:

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Deadline: September 19, 1983

Chapman Conference on Collisionless Shock Waves in the Heliosphere

February 20–24, 1984
Silverado Country Club and Resort
Napa Valley, California

Convenor: R. G. Stone

Abstract Deadline:
November 1, 1983

Invited reviews and contributed papers in the following general areas: Overview of the collisionless shock, macroscopic aspects of shocks, microscopic aspects of shocks and particle acceleration. Typical subjects to be covered include:

- Why and where shocks form in the heliosphere?
- Shock dynamics and evolution.
- Shocks associated with solar activity, planetary bow shocks, corotation shocks, and shock-shock interactions.
- Subcritical, supercritical, quasi-parallel, and quasi-perpendicular shocks.
- Dissipation mechanisms.
- The foreshock.
- Particle acceleration mechanisms.

Contact: AGU Meetings, 2000 Florida Avenue, N.W., Washington, DC 20009
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GAP

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1715 Electric Fields
THE DISTRIBUTION OF AURORAL ELECTROSTATIC SHOCKS BELOW 8000 KM ALTITUDE
B. I. Bennett (Physics Department and Space Science Laboratory, University of California, Berkeley, California, 94720), M. Temerin, and F. S. Mozer

This paper examines the distribution and characteristics of electrostatic shocks as observed by the S3-3 polar-orbiting satellite. There is auroral oval coverage by the satellite at all magnetic local times and at all altitudes between 240 and 8000 km. Electrostatic shocks are reasonably uniformly distributed in magnetic local time, with a slight increase in the probability of occurrence in the cusp region and a decrease in the post-midnight region (0 – 6 hours magnetic local time). The occurrence of shocks increases sharply with altitude up to 5000 km, and at a slower rate above 5000 km altitude. Larger shocks tend to occur above 5000 km altitude and between 18 and 22 hours magnetic local time. Electrostatic shocks occur in or near the latitudes of the auroral oval, with few shocks occurring inside the polar cap. Only during periods of high K_p do shocks occur at low latitudes. Shocks occur with greater probability at low altitudes (1000 – 4000 km) during winter periods than during summer periods. In addition, a comparison of upward flowing ion beams with electrostatic shocks showed that energetic ion beams are associated with shocks but low energy ion beams are not, indicating a possible potential threshold for shocks in ion beam regions. Also, a search for upward flowing ion beams near electrostatic shocks at altitudes below 4000 km showed that upward flowing ion beams occur between 1000 – 4000 km altitude and between 11 – 24 hours magnetic local time with at least a 10% probability.

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